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Impacts of Technology on U.S. Cropland and Rangeland Productivity

Volume II—Background Papers

Part B

Paper No.

8. Impacts of Technologies on Productivity and Quality of Southwestern Rangelands
9. Technology Issues in Developing Sustained Agricultural Productivity of Alaskan Virgin lands
10. Impact of Communications Technology on Productivity of Land
11. Land Use Planning Technologies Applied to Croplands and Rangelands
12. Sustained Land Productivity: Equity Consequences of Technological Alternatives
13. Multiple Cropping Systems: A Basis for Developing an Alternative Agriculture

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Preface

This volume contains papers written for OTA to assist in preparation of the report *Impacts of Technology on U.S. Cropland and Rangeland Productivity.* OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information than could be accommodated in the final assessment report, and are being made available for such purposes.

Background Paper No. 8

IMPACTS OF TECHNOLOGIES ON PRODUCTIVITY AND QUALITY OF SOUTHWESTERN RANGELANDS

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Office of Technology Assessment
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This background paper was prepared for the assessment "Impacts of Technology on U.S. Cropland and Rangeland Productivity." The views expressed are those of the author(s) and not necessarily those of OTA.

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Background Paper No. 8

Abstract

IMPACTS OF TECHNOLOGIES ON PRODUCTIVITY AND QUALITY OF SOUTHWESTERN RANGELANDS

by

Don D. Dwyer

The southwestern rangelands of Arizona, New Mexico, and Texas and Oklahoma Panhandles west of the 100th meridian contain some 214 million acres. They are currently estimated to be producing at 25 to 50 percent of their potential. The main factor responsible for the current productivity status is the combination of historic overgrazing and recurring droughts. Replacement of entire grasslands by less desirable mesquite and other brush species have been the result of this past range use.

Flagrant overgrazing has, except for unusual instances, been corrected and these ranges are now mostly in a static ecological condition. That static condition is not desirable, either for livestock or wildlife, and positive, direct actions need to be taken to turn the trend toward improvement.

Reduction or elimination of grazing is not the proper action since research shows that brush-dominated southwestern range will not improve through natural succession in any reasonable period of time, even if grazing were to be eliminated.

The avenues suggested for improving the productivity and quality of southwestern rangelands are:

1. Increased application of known technologies through aug-

mented state and federal activities for range management extension. Funding of the Forest and Rangelands Resources Extension Act of 1978 would provide an avenue for this to be accomplished.

2. Increased support for range management programs of federal land management agencies. This means increasing personnel and funding for range improvement projects, but equally important is to enhance efforts to gather resource inventory and monitoring data which will support the land use decisions that must be made.

3. Address at the national policy level the issue of the inadequate level of knowledge we have about the southwestern range resource. Despite its inherently low productivity due to its aridity, it is a very important but seriously neglected national resource.

4. Bring the national research funding levels for rangelands research more in line with the magnitude, complexity and importance of the resource. This could be helped along by Congressional support for a Rangelands Research Bill similar to the well-known McIntire-Stennis forestry research bill.

5. Use the program priorities set forth by the Western Regional Task Force for range research as guidelines to develop new and innovative research projects. An enormous increase in both basic and applied research is needed which addresses the problems of range productivity for livestock production.

6. Government and its agencies must become more aware of the impacts of their policies on the social fabric of southwestern economics. It is recommended that human as well as ecological responses be considered and that preservation of ranching as a way of life be a goal, not an alternative. An openly positive role for rangeland improvement rather than the currently perceived role of regulation and confusion is needed.

7. Develop a single, acceptable technique for inventorying and monitoring rangeland change to be used by all federal land management agencies. This will insure future comparability of data between agencies.

The main point of this paper is that the productive capacity of the southwestern rangelands could be more than doubled with proper application of current technology and increased support for rangeland research.

Background Paper No. 8

IMPACTS OF TECHNOLOGIES ON PRODUCTIVITY AND QUALITY OF SOUTHWESTERN RANGELANDS

Ranching In The Southwest

Nearly 90 percent of the land area of the Southwest can be classed as grazing land (Talbot 1957). It sustains and produces several million head of livestock and wildlife, even though the climate and vegetation in the Southwest are not ideally suited for livestock production. The climate is too hot and dry without development of water facilities. Precipitation occurs too late in the year to provide growth of range forages during the critical spring calving period. Droughts are endemic and periodically reduce range forage production and stock water supplies to critically low levels, and high winds and low humidity reduce the effectiveness of the limited precipitation that does occur. Likewise, range vegetation is sparse, and soils erode badly during high winds or infrequent heavy downpours, and are subject to invasion by low-valued brush and scrub trees (Goodsell, et al. 1974).

With these shortcomings, most of the land of the Southwest can be economically used for little other than livestock grazing. For this reason, the discussions in this paper will emphasize the response of southwestern rangelands to grazing and will deal with traditional rangeland measures of production in terms of plants and soils, and attempt to describe how various uses have impacted on the rangeland resource.

The big ranches in the United States are found in the Southwest. Nine of the 15 largest ranches in Texas are west of the 100th meridian, with sizes ranging from 167,000 to 370,000 acres. Over half the ranches in the United States with acreages over 20,000 are located in the Southwest (Williams 1971). There are perhaps a dozen ranches in each of Texas, New Mexico and Arizona with greater than 100,000 acres. Despite these references to grand scale, however, more important with regard to technology application are the small ranchers, because there are so many more, and collectively they control so much more land. The average-sized ranch in the Southwest is a commercial, family-operated ranch of about 11,000 acres (Gray and Goodsell 1961).

Measuring Rangeland Productivity

To determine the impact that current technologies have on the quality and productivity of the southwestern rangelands requires that one understand the interrelationships among the vegetation, the climate, and the grazing animal.

One can measure rangeland productivity in terms of kind and amount of plant species present which reflect the ecological potential or range condition (quality) of the area. Another measure of rangeland productivity could be made indirectly through livestock by determining such items as offspring percentages, death loss percentage, market weights, and thus economic return. All these animal measures are directly affected by the plant species present and overall forage production of the rangeland. Though not a measure of production per animal unit, the number of livestock which can be grazed on a given area of rangeland (carrying capacity) is also a direct measure of range productivity. Climate, especially precipitation, is an integrating factor which imposes an extremely critical influence on how plants and animals respond to their rangeland environment.

Another important measure of rangeland productivity is the ability of the range to sustain not only livestock grazing, but to provide "environmental services" such as maintenance of wildlife and fisheries, watershed qualities, scenic values, recreation opportunities and archeological resources.

The paper will discuss past, present and emerging technologies as they relate to rangeland and assess future possibilities for improvements.

Rangeland Ecosystems Of The Southwest

Generally considered, the southwestern United States west of the 100th meridian is mostly rugged, usually dry, inhabited with plants and animals which sparsely populate the land, yet are able to survive and grow in the generally inhospitable environment. Over the region, precipitation averages less than 12 inches annually.

Location

Geographically, the southwestern range area includes Texas and Oklahoma west of the 100th meridian and all of New Mexico and Arizona (Figure 1). An estimated 214 million acres are bounded by the area.

Geography

Many geographers insist that most of western America from the 100th meridian is primarily desert; even the mountain ranges being mere oases (Lavender 1980). For the Southwest this is generally true, being often identified with the two huge deserts, the Chihuahuan and Sonoran, that extend to their northern limits from the Mexican states that share their names. The Chihuahuan Desert, with its dry, relatively few mountains, has El Paso as a point from which the desert spreads westward for a hundred miles, extends up the Rio Grande for 250 miles to Albuquerque, and east across the Pecos River to encompass the Big Bend National Park. This is a relatively high desert, mostly with elevations above 3,500 feet.

Included within the geography of the Southwest are several mountain ranges such as the Sangre de Cristos, the Sacramentos, and the San Franciscos. The tallest peak in the Southwest slightly exceeds 13,000 feet. Thanks to the mountains there are some major perennial

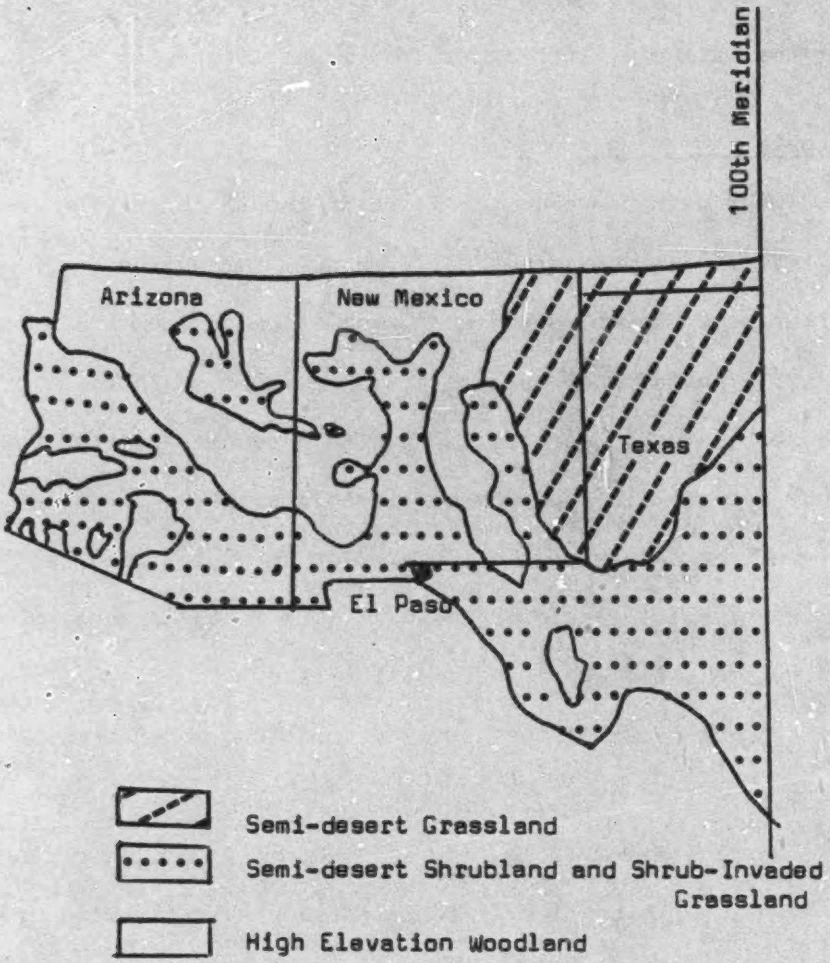

Figure 1. Rangelands of the Southwest

rivers--the Canadian, Pecos, Rio Grande, Chama and San Juan in New Mexico and the Colorado and Gila in Arizona. That's not much water for the nation's fifth and sixth largest states.

Climate and Drought

When rain comes in the heart of the Southwest, it comes mostly in late summer and early fall from July through October. Toward the eastern boundary in Texas and Oklahoma Panhandles the rain may commence as early as May and westward there may be more in the winter months of December through February. The high mountains receive their share of snow, but snow is uncommon at elevations below 4,500 feet.

All across the region, elevation has a most profound effect on the amount of precipitation received. Near Yuma, Arizona, at an altitude of 100 feet, the average rainfall is about four inches per year, while the highest parts of the Sangre de Cristo mountains receive forty inches for the year.

Precipitation is low and erratic and recurring droughts are the rule, not the exception. Precipitation interplay with grazing is tremendous and its impact, both above average and below average amounts, is confusing, if not impossible, to assess. In one study, Goodsell, et al. (1974) noted weather conditions varied so widely in the Southwest from 1964 to 1972 that trends in production parameters they were attempting to measure were masked.

Most of the region is characterized by short-duration, high intensity summer thunderstorms. West Texas and eastern New Mexico and the Oklahoma Panhandle receive rainfall originating from the Gulf of Mexico in the amount of 16 to 18 inches per year. Moving westward across the middle of the region, rainfall diminishes to 12 to 14 inches, then 8 to 12 inches in the Chihuahuan Desert, and 4 to 12 inches in the Sonoran Desert, depending on elevation.

Natural Vegetation

Most of the southwestern region can be classified as semi-desert, grass-shrub ecosystems (Martin and Cable 1974), though the portions above 6,000 feet elevation are tree dominated.

Vegetation varies greatly depending mostly on precipitation and elevation. The four general vegetation types are grasslands, brush-invaded grassland, semi-desert shrub and woodland. The grasslands and brush-invaded grasslands occur mostly in the high plains of Texas, the Oklahoma Panhandle, and eastern New Mexico (Figure 2). Local grassland areas are also widely interspersed with semi-desert shrub.

Generally, the southwestern semi-desert grasslands and shrublands are closely associated types and the two occupy more than 116 million acres in Arizona, New Mexico and Texas west of the 100th meridian (Price 1974). Remaining portions of the Southwest below about 5,000 feet in elevation are semi-desert shrub. Woodlands exist mainly at elevations about 5,000 feet. Juniper and pinyon pine characterize the vegetation at these intermediate levels and at higher elevations beginning at around 7,500 feet elevation, Douglas-fit, ponderosa pine and true fir species are found.

Important grasses are blue and black grama (together with perhaps ten other species of _Bouteloua_), curly mesquite, tobosagrass, dropseeds (_Sporobolus_, several species) and buffalograss. Important shrubs are

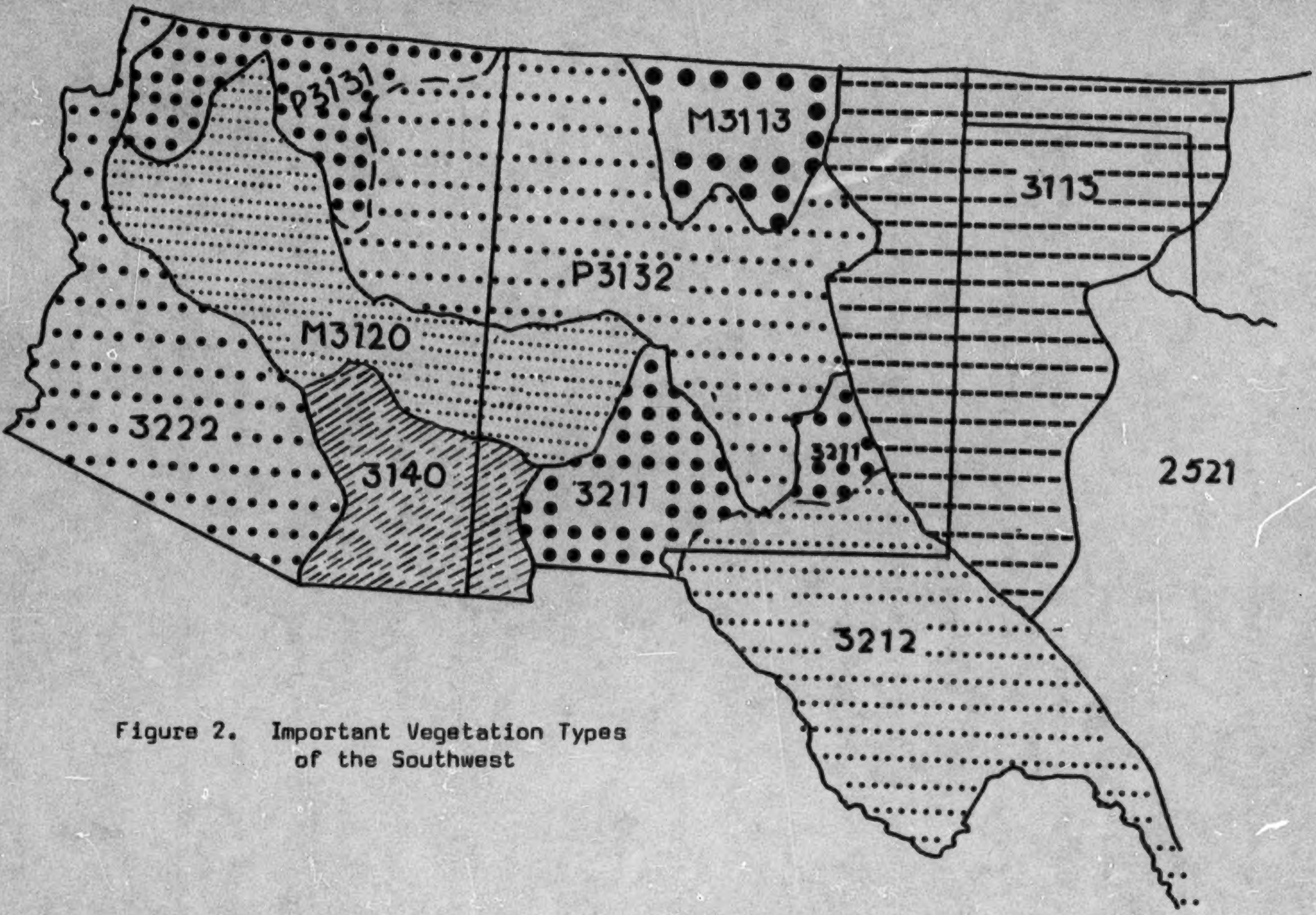

Figure 2. Important Vegetation Types of the Southwest

3222 - Creosotebush-Bursage shrubland

3140 - Shrub-grassland

M3120 - Gila Mountain Forest

P3131 - Juniper-Pinyon and Sagebrush Saltbush Mosaic

P3132 - Grama-galleta Semi-desert and Juniper-Pinyon Woodland Mosaic

3211 - Grama Tobosa Semi-desert grassland

3212 - Tarbush-Creosotebush shrubland

2521 - Mesquite invaded buffalograss

3113 - Grama-buffalograss Semi-desert grassland

3140 - Shrub-grama grassland

mesquite, catclaw, shinnery oak, yucca and numerous succulents such as prickly pear and cholla cacti.

Soils

Soils of the Southwest may be broadly described as immature, rocky or sandy on the uplands and loamy or clayey in the lowlands and floodplains, low in fertility and highly erosive. The only tillable soils are found in the valleys and floodplains where irrigation is available.

Inherent Natural Resources

Climate and soils are the natural constraints on biological productivity of southwestern rangelands. Low rainfall and soils low in fertility preclude cultivated agriculture so livestock production is the chief agricultural enterprise of the region. Less than ten percent of the land is tillable and that, only with irrigation. As in any arid region, water is the most important inherent resource. Its scarcity for all forms of life draws attention to its importance as demands for its use increase.

Forage is a flow resource, replacing itself naturally year after year. But in the Southwest, the primary productivity of this flow resource is relatively low. Generalizing, rangeland in good condition in an 8 to 10-inch rainfall zone, an area that would encompass perhaps two-thirds or more of the Southwest, would produce an average of about 180 pounds of dry matter per year per acre for animal consumption (Price 1974). Nevertheless, because of its immense size, forage production from the rangeland is very important to the economy of the southwestern region. An increase of 50 percent above its present amount, which is probably nearer 100 pounds per acre overall than the 180 pounds cited above for good condition range, would provide enormous benefit to the region.

In addition to the grazing resource, the climatic, scenic, and cultural values for human living conditions are renowned. The population centers have grown far faster than other regions largely because of these values. This influx of population continues to place an ever-increasing burden on the inherent water resources of this area, and the need for more water grows greater each year.

Recreation demand for permanent as well as temporary residents is growing and the public lands of the Southwest are being called on each year to sustain greater and greater human activity. Recreation vehicles are allowing people to push farther into heretofore unreachable places.

Land Ownership Patterns

In the Texas and Oklahoma Panhandle portions, 90 percent of the land is privately owned and ten percent is owned by state institutions (Goodsell, et al. 1974). In New Mexico (78 million acres) and Arizona (73 million acres), 34 and 45 percent, respectively, are federally owned (Nielsen and Workman 1971). These latter two states have several large national forests, parks and monuments, two large military installations and several Indian Reservations. More Indians live in the Southwest than in any other section of the United States. The land area they control approximates 26 million acres, 26 percent of Arizona and 9 percent of New Mexico (Lavender 1980).

The typical southwestern livestock ranch utilizes land leased from federal, state and private sources as well as its own private, deeded land.

History And Use Of Southwestern Rangelands

Grazing History

Grazing by domestic livestock in the Southwest dates back to about 1500. The stock of Cortez, mostly horses and sheep, spread from Mexico into what is now the United States (Thompson 1942). Coronado, in his journey in 1540-1542 from Mexico through present southeastern Arizona, across New Mexico, northwestern Texas to southwestern Kansas, had with him 1,000 horses, 500 cows, and 5,000 sheep. These were lost, strayed, and stolen to the extent they furnished the nucleus for later herds (Thompson 1942).

During the period 1860 to 1880, livestock numbers grew dramatically, and it is said that for the Southwest as a whole, the numbers were probably as great around 1900-1920 as they have ever been (Wagner 1978). Thus the Southwest was not only grazed earliest but numbers of livestock increased more rapidly than for most other regions of western America. The early development of the range livestock industry in the United States was characterized by little attention being given to either the animals or the land they grazed (Dwyer 1979).

Apart from the original inhabitants, the Indians, the next longest span of history was influenced by the people of Spanish and Mexican descent. The first colonists settled the Rio Grande in northern New Mexico in 1598 (Lavender 1980), the time grazing for livestock production there is thought to have begun. This was associated mainly with the Spanish Mission Churches.

In 1962 it was estimated that one million cattle grazed yearlong on the semi-desert, grass-shrub ranges in Arizona, New Mexico, and

West Texas excluding the Panhandle (Paulsen and Ares 1962). The number for that portion of the Southwest today would be somewhat, but not greatly, more.

Vegetation Changes--Changes in vegetation of the lower elevations of the Southwest have been of two kinds, invasion of grassland by woody species and changes in kinds and amounts of non-woody species (Humphrey 1958). The major actor of the shrubs and small trees has been mesquite (Prosopis) which covered an estimated 70 million acres of southwestern rangeland in 1952 (Parker and Martin 1952). Some authors, including me, estimate that figure at nearer 100 million acres today, nearly half of the southwestern region.

To illustrate how shrubs have increased their control, on the Jornada Experimental Range near Las Cruces, New Mexico, mesquite dominated only 4.8 percent of the area in 1858, but this had increased to 50.3 percent by 1963 (Herbel, et al. 1974). Other shrubs such as creosotebush and tarbush also increased significantly.

Control of wildfire beginning in the early 20th century may have been an important factor in permitting woody plants to extend their range into grasslands (Humphrey 1958).

Generally speaking, and from the livestock producers' viewpoint, the vegetational change has been bad. Ungrazeable plants have replaced forage. The grama (Bouteloua) and tobosa (Hilaria) grasses have declined in abundance and productivity.

Other Rangeland Uses--Approximately 20 percent of the Southwest is high elevation, ponderosa pine and Douglas-fir forests. These lands, mostly National Forests administered by the Forest Service provide timber, valuable wildlife habitat and hunting, summer grazing for sheep and cattle, high quality recreation opportunities and critical watershed for many cities and towns. Uses of Southwestern lands for other than grazing have historically been limited. Except for mining, which was very localized, little but domestic livestock, wildlife and weather extremes has had significant influence on the rangelands prior to the 1960's. The 1960's saw a remarkable growth in public awareness of the western range. Recreation use in national parks, wilderness areas and dispersed recreation on public lands increased tremendously, as has concern for the welfare of wildlife and interest in viewing it.

Virtually all southwestern rangeland is now used for multiple purposes. The serious conflicts that first arose in the 1950's and 1960's over multiple use have mostly been resolved, at least for public lands. Unrestricted use of off-road recreation vehicles continues to cause plant and soil damage of significant proportions.

Even with these recent changes both in attitude and use of rangelands, the major impact of southwestern rangelands is and will continue to be grazing by domestic animals and wildlife.

Status Of Present Southwestern Range Productivity

Rangelands vary greatly in their capacity to support livestock and other uses because of differences in amounts and patterns of precipitation, soil productivity, topography, and vegetation type. For the Southwest, these differences are even greater than for the general condition the statement represents. For plants especially, the basic resource for the grazing animal, the environment is harsh and stressful.

Southwestern rangelands are currently estimated to be producing at between 25 and 50 percent of their potential (Box, et al. 1977). Goodsell, et al. (1974) reported in their study of southwestern cattle ranches representing extreme west Texas, southern New Mexico and southeast Arizona, that on the average there were 82 acres of land in farms and ranches per cow or heifer (not calves). The average land base for ranches in their study consisted of 28 sections of privately owned land, six sections of land leased from other individuals and five sections leased from state or federal government. This totaled 24,960 acres. The number of cattle on this "average" ranch ranged from 360 to 380 head during the 1964-1972 study period, which represents an average yearround stocking rate of about 68 acres per animal, including bulls and replacement heifers and ignoring unweaned calves.

Assuming the ranches in the Goodsell, et al. (1974) study are representative of the southwestern ranges, i. e. at 25 to 50 percent of their potential productivity, it means these ranches could be capable of supporting closer to 700 head of cattle on the same land base.

The decline in productivity probably reaches its low point for the western range as a whole in the decade of the '40's (Box, et al. (1977). Livestock numbers generally were reduced throughout the four decades 1915-1955 as experience demonstrated the relationship between the forage resource and animal numbers, and as federal land management agencies instituted regulations and policies to control grazing on the public lands.

The USDA Forest Service Report No. 19 (1972) estimated that for all federal lands 18 percent was in good or excellent condition, 50 percent was in fair, and 32 percent was termed poor or bad. The current Resources Planning Act Assessment (USDA 1980a) provides estimates of the status of rangeland productivity. The implication of this report is that southwestern rangelands are far below their ecological potential. Firm data, however, are sketchy which will document the trend in condition of these rangelands.

Prevailing opinion among western range scientists is that the rangelands are presently not only below their potential in productivity, but also are essentially static in trend. On balance, livestock and wildlife numbers now are such that the rangelands are being maintained at their relatively low ecological condition or are only slightly improving. This is a generalization, of course, for it is recognized that in specific instances there are serious examples of grazing abuse as well as examples of greatly improved rangelands.

Can the Current Productivity Status Be Changed?

It is clear to range ecologists who have done extensive research over a number of years that natural plant succession will not restore the southwestern rangeland to its former productivity in any reasonable period of time. For example, once woody plants have gained competitive control of the plant community, reduction or elimination of present grazing will not result in significant range improvement, even though grazing may have been the significant factor causing the deterioration.

The present status is reversible, but positive, direct action is essential now to restore rangelands to a level more in line with their potential to better meet the needs of society. There must be a wider application of the known management principles as well as the application of new and emerging technologies. Further, new research should better address the specific needs of the southwestern rangelands.

Technologies For Southwestern Rangelands

Those who are familiar with the status of technology applicable to rangeland management and livestock production are disappointed with the limited extent to which it is applied. Inadequate application of new methods is probably as well manifested in rangeland use and management as in any segment of agriculture.

Current Ranching Practices

Using a cow-calf ranch as an example, we see production practices are similar throughout the Southwest. Goodsell, et al. (1974) describe this as follows. The rangelands are grazed continuously yearlong. Cows are bred to calve in the spring and calves are weaned and sold mostly in the fall. Heifers are usually bred to calve as two-year-olds. Cattle graze native range except for occasional brief periods in severe winter seasons when hay may be required. Little part-time labor is hired during the year except for spring branding and associated activkties, and fall marketing.

Ranchers customarily feed supplements such as cottonseed meal to their livestock January through March to overcome protein deficiencies in the native forage. In extreme drought years this period of supplementation may be extended and hay may be fed. The kind of ration fed is adjusted to complement the nutrients available in the native forages.

Prior to 1960 almost all southwestern cattle were Hereford and Angus breeds. Presently, nearly all ranches practice cross-breeding to some extent with perhaps twenty different breed combinations represented over the region.

With regard to ranch improvements, water development has held the attention and resources of most southwestern ranchers. Livestock are not handled much. Ranchers only see most or all of their animals when they are moved over the ranch, during calving, at branding, during winter supplementation and at marketing. Minimum rather than maximum herding is the rule.

Goodsell, et al. (1974) noted also that in general, ranchers are slow to adopt new technology except for a few specific practices such as animal breeding, preventive medicine, transportation and certain types of range improvements. Their survey of 63 southwestern ranchers with 200 to 500 head of cattle showed that only slightly over half the ranchers had "attempted" to install or adopt plastic pipelines, selective breeding programs, rotation or deferred grazing and brush control programs by 1970. The most popular technologies were those associated directly with the animals.

Ranching in the Southwest usually represents a mix of technologies. One extreme may include the rather old-fashioned practice of roping and branding on the open range, while the other extreme might see the use of a top line bull in a rather complex breeding system, with both extremes represented on the same ranch. Few, if any, ranches are known to apply only new and emerging technologies throughout the enterprise.

Techniques Available for Wider Application

The range management technologies described below have been developed from research conducted over the past several decades. There are examples where one or more have been used in various ranching operations. It would be an exaggeration to say the technologies have been universally applied.

Watering--The dry rangelands of the Southwest are continually plagued by inadequate free water for livestock and wildlife. Cows consume about 10 to 12 gallons of water daily and so facilities and techniques for furnishing this water are critical. Even today there are many range areas in the Southwest where water is simply not available yearround for animals. For New Mexico, the Conservation Needs Committee (1970) indicated that there should be a water facility for every 600 acres. Under present technology this leaves half of New Mexico inadequately served. No doubt this is true of the other southwestern states as well.

In addition to the animals' requirement, water provides an ideal technique to distribute the grazing animals more evenly over the range. Since they tend to congregate near the watering facility and can travel only about a maximum of four miles in the case of cattle and ten miles for sheep, the more watering places there are the better and more even the grazing utilization will be. Additional water for livestock also means more water for wildlife, thus enhancing habitat resources for many wild animal species.

Grazing Systems--Southwestern rangelands are known to be suited for continuous yearround grazing, and most current practices follow this grazing system. Limited research suggests that rangeland productivity could be increased and the ecological condition of rangelands improved if proper rotation systems of grazing were applied that permitted periods of "rest" from grazing (Herbel, et al. 1971).

We have learned that plants survive and grow better when not continuously grazed, even at a moderate level. Grazing studies involving various "systems" of cattle management show that vegetation improves in kinds of plant species and their vigor if allowed periodic "rest" from grazing, even though the range may be grazed intensively at other times during the year or season.

While research does not show universal improvement in livestock production under specialized grazing systems, it does show that range condition and thus carrying capacity are consistently improved (Herbel 1971). This is important since grazing systems provide a significant tool for improving the condition of southwestern rangelands while at the same time not requiring a reduction in livestock numbers.

The "best pasture" system as described by Herbel, et al. (1974) appears to be more applicable to southwestern range conditions than any other, but it has not been adequately researched nor has it been compared extensively with other grazing systems.

Flexibility in herd management, regardless of the grazing system used, is am important key to proper range management and continued long-term range productivity (Dwyer 1979). It is recommended that female breeding stock not exceed 60 percent of herd numbers, with replacement females, males, and castrated males making up the rest. This allows quick reduction in stock numbers in times of severe drought stress without doing serious, longterm damage to the basic herd reproductive resource.

Further, Ragsdale, et al. (1969) feel that the herd or flock numbers should not exceed 80 percent of the average estimated carrying capacity of the range, thus providing a margin of safety for fluctuations in forage quantity.

These grazing systems and the flexibility described are methods of coping with ever-threatening drought. They represent current technologies, rudimentary as they may seem, and this includes the simple technique of stocking the range at less than its estimated grazing capacity.

Brush Management--One of the most serious ecological problems on southwestern rangelands has been the dramatic change in vegetation patterns that has taken place since settlement. Generally speaking, less desirable plant species have increased at the expense of more desirable ones. Often shrubs and low-value trees have increased to the point where watershed protection values are low, productivity for grazing by livestock and wildlife is low, and erosion is a serious problem.

Encroachment of woody plants, especially mesquite, in the semidesert shrub-grass range has been called the biggest contributor to decreased rangeland productivity in the Southwest. The combination of historic overgrazing, recurring drought and the astonishing aggressiveness of the shrubs have led to their widespread invasion into land originally dominated by grass. Even under proper grazing, mesquite will continue to invade open grassland and increase its density in old stands (Parker and Martin 1952).

Research by Herbel, et al. (1974) showed that when mesquite was reduced to 50 percent of its original stand by spraying with the herbicide 2, 4, 5-T, production of perennial grasses increased from 32 to

232 pounds (625 percent) per acre at one location and from 84 to 463 pounds (450 percent) per acre at another. This illustrates how effective mesquite can be in suppressing grass production and also the tremendous potential to increase productivity for livestock grazing if the mesquite is reduced. It has been conservatively estimated that when properly done on appropriate sites, livestock production could be doubled for the shrub-invaded areas treated to control undesirable shrubs.

Problems arise with employing both the chemical and the mechanical methods of brush control. The use of chemicals such as Tordon, 2, 4, 5-T, 2, 4-D and others is strictly controlled by federal regulations. Mechanical means such as plowing or bulldozing requires the use of energy hungry equipment, making costs largely prohibitive for the inherently low-producing Southwest.

Combination Stocking--Ragsdale, et al. (1969) feel that the optimum combination of livestock species for the vegetation near Barnhart, Texas (slightly east of the southwestern region discussed here) is 50 percent cattle and 25 percent each of sheep and goats on an animal unit basis. From research done there, overall livestock production under this scheme was increased by 20 percent. The number of big game animals was also significantly increased as a result of the combination stocking which improved habitat conditions.

Reseeding--Replanting depleted rangelands is a technique that cannot, with current technology, be widely applied in the Southwest, since the precipitation is below the minimum necessary to assure success for much of the area. Where rainfall exceeds 12 inches annually and the soil has not been severely eroded, southwestern rangelands may be reseeded, but the risk of failure is still high. Research is underway to develop equipment and techniques that would increase soil moisture for seedlings and for plant establishment by impounding runoff water in small artificially-formed basins. This would be considered an emerging technology. More research directed toward both reseeding and brush control to make them environmentally acceptable and economically viable for arid rangeland is required.

Other Techniques--There are many minor range improvement technologies which should be instituted if full benefits from southwestern ranges are to be realized. These include techniques for improving livestock grazing distribution, fencing to better utilize various range sites, proper location of water, interseeding, pitting and furrowing to improve water retention and infiltrations, runoff water management, and rodent and insect control. Properly applied and used these all contribute to increased rangeland productivity.

Adequacy Of Knowledge About The Range Resource

It is true that there is more general knowledge which could increase southwestern rangeland productivity than is now being applied, but this is not the whole story. Information relating to animal grazing distribution, specialized grazing systems, vegetation control and manipulation, and numerous practices related specifically to the animals is available, but the research base even for these practices does not have the depth and perspective needed for the future, and the data provided is useful mostly for intuitive conclusions.

Scientists

Current knowledge for management applied to southwestern rangelands has come both from longtime observation and research. There has never been a large cadre of scientists researching range problems. Even now, despite the much greater national interest in the western range, the number of range scientists is extremely small, given the magnitude, complexity, and importance of the resource. Box, et al. (1977) compared the number of scientists in range science with forestry, for example, and found that in 1972, in federal forestry research, there were a total of 437.4 full-time equivalent (FTE) researchers. For range research this number was 21.3. In 1974 the number of FTE federal range scientists declined to 20.1, while the total scientist years in forestry research increased to 524.1. When numbers of all range scientists are totaled, including those in land-grant institutions, there were 61.3 FTE scientists addressing rangeland problems nationwide. The conclusion here is that out of 671.5 scientists researching forest, pasture and rangeland problems, 61.3 are range scientists (Box, et al. 1977), although rangelands make up nearly half the continental United States and provide the basic resource for the country's entire range livestock industry. Overall, I feel range research has been greatly underrepresented in the nation's agricultural research mission.

It is little wonder, then, that the research conducted relative to southwestern rangelands is wholly inadequate to the need. The knowledge we have is too broad and for the most part superficial. This is not a criticism of the scientists, but to state without reservation the problem arises from the fact that the past and present support base for research is far too small.

Public Land Managers

The federal and state land managers responsible for over 75 million acres in the Southwest are confused, reeling from lawsuits, and deficient in qualified personnel to accomplish Congressional and court-mandated policies. The agencies are being criticized presently for making decisions to reduce grazing permits on federal lands. They are criticized by ranchers because the ranchers claim the cuts are too high or not needed at all, criticized by environmental protection organizations who claim the grazing reductions are not great enough, and criticized by range scientists who feel there is insufficient scientifically acceptable data on which to make the decisions being made.

The intent of the federal land managers is to "improve" the range by reducing grazing pressure. But first it needs to be determined whether or not the range is improving or declining in condition under the present grazing rates.

Confronted with Environmental Impact Statements to develop and multiple-use conflicts to resolve, these managers need a firm data base from which to draw. Simple, but obviously important questions are asked daily of researchers who must respond that no data are available. Some of these questions may serve to illustrate.

> How much land in New Mexico is in "fair" condition and what is its trend?
>
> Which specialized grazing system will improve a desert grassland range more rapidly than continuous grazing?
>
> How long and at what times during the year must blue grama grass be rested from grazing for it to achieve its potential productivity?
>
> How can we separate the climate-induced changes from grazing-induced changes in southwestern rangelands?
>
> What methodologies are most appropriate to determining range condition and trend on southwestern ranges?
>
> How closely are range condition and livestock production related?

Obviously, any science can list questions that need answers, but these are elementary, and are essential to bringing about any increase in the productivity of southwestern rangelands.

In addition to the many unanswered questions facing public land managers, there are far too few managers themselves to deal with the enormous land area. Agencies do not provide sufficient opportunity for the professional land manager to stay current with the technology through short course educational opportunities as well as advanced training. It appears that the agencies provide far too little incentive for their personnel to stay academically and intellectually strong and active in the professional societies. It would be wise if universities would be more receptive to the needs to up-date land management professionals and for federal agencies to be more responsive to the educational opportunities that exist in the western Land Grant Universities.

Ranchers

Most early ranchers had neither the ecological knowledge on which to draw nor an interest in managing the plant and soil resource. In fact, there was great doubt on the part of many early graziers that rangelands required any management. The intent was to graze all the grass with their livestock, for not to do so meant the feed was lost. Overconfidence that there was plenty was followed by overuse.

That ranchers even today are not applying the knowledge we now have is sad but true. What is not so clear, however, is why it is true. Is the reason strictly one of economics? Is it ignorance? Is it because ranchers feel the old way of doing things is best? Or is the reason because the ranchers do not have enough information to allow taking the financial risk required of almost any technology application. I feel it is largely a function of the latter. To get current knowledge applied to the land will require a much greater educational effort conducted by range management extension specialists state by state. The minimum effort should be at least as great as that now given to beef cattle and sheep production or pest protection.

Research And Extension Needs And Priorities

Range Research Needs

Collectively, current research on southwestern rangelands is small, disorganized, random, shallow and without well-defined central purpose. It has always been and continues to be largely descriptive and on a broad scale. There are reasons why this is so.

Research on rangelands is relatively young, so there has not been enough time to evolve a "grand plan" for southwestern range research. Reports of botanists and ecologists were made concerning the southwestern range as early as 1895 (Smith 1895), but serious research was not reported until between 1915 and 1920 by plant ecologists who measured and interpreted responses of native plants and plant communities to various environmental influences, especially grazing. Range scientists, per se, were not recognized as such in government bureaucracies until the 1940's. The first Ph. D. in Range Science was not graduated until 1952.

Through the years a few dedicated researchers have provided a general understanding of plant community dynamics and interactions which, when interpreted for livestock production, have been useful and effective. This historical research very successfully described the undesirable ecological consequences that occurred when numbers of grazing animals exceeded the ability of the plant communities to sustain them. The early research granted a basis for bringing livestock numbers and range plant production into better balance during the 1930's and 1940's.

Proper range management for the future, however, will require a much more sound research base than now exists. Box, et al. (1977) pointed out that much needed data fall into two categories. The first is the store of basic research data and principles about the resource which can be applied in initially formulating a management program. The second is a series of periodic surveys and assessments with which administrators can continually evaluate the status of the resource and assess its response to a given management program. In their opinion, cases of improper management plans and federal administrative paralysis resulting from public outcries can be traced directly to the deficiencies public land management agencies have in those two categories of data.

The initial research information necessary will come from an accurate assessment of the current status of the southwestern rangelands in relation to their potential. This will require inventory data on acreages of various range sites (productivity units) and their range condition class (ecological quality and productivity).

A Western Regional Task Force has developed for all western rangelands some broad research program areas which are quite applicable to the southwestern region (Klemmedson, et al. 1978). Ranked in order of priority these are:

1. Dynamics of Individual Plants and Plant Communities.
2. Identification, Classification and Inventory of Range Ecosystems.
3. Improvement of Rangelands for Increased Productivity.
4. Short and Longterm Grazing Impacts (on rangeland resources).
5. Influence of Economic, Social and Political Constraints on Management of Range Resources.

The Task Force noted that to increase the productivity of rangelands (priority 3) would require a great deal of background knowledge obtained from priorities one and two, which are not now available. Included in number 2 should be emphasis on development of methodologies, especially a single method for range inventory and monitoring which would be suitable for all agencies responsible for management of public rangelands.

I feel these five subject areas for rangeland research published in 1978 are still current. They are basic to the overall need. Congressional support for them would go far in meeting requirements for increasing southwestern rangeland productivity and a possible avenue for this could be the Rangelands Research Bill which has been referred to committee.

Range Extension Needs

To get knowledge properly applied by land users will require a larger sustained effort in continuing education and extension than we now have. Ranchers are widely dispersed, and to get the necessary information to them will call for more creative approaches and more persistence than the few people now available have been able to provide in the past.

Presently, there are only about 15 full-time range extension specialists supported by state and federal money for the eleven western states. To educate the ranchers and other land users of such an enormous area is simply too great a responsibility for so few range extension personnel.

The priority of action would first be to augment range management extension by supporting a much larger number of trained people to do the job. The program should then include three modes: 1) on-ranch and short course continuing education, 2) demonstration projects on the land which represent successful application of technologies where field days can be held, and 3) television cassette educational packages.

These needs could be very well addressed, if not fully met, by funding the Forest and Rangelands Extension Act of 1978.

Impacts Of Current Governmental Policies On Rangeland Productivity

Since 1960 Congress has passed the following Acts which directly or indirectly affect southwestern rangeland productivity.

Multiple Use-Sustained Yield Act of 1960
Clean Air Act of 1963 (Amendments 1970 and 1977)
Wilderness Act of 1964 (Amendments 1972 and 1977)
National Environmental Policy Act of 1969 (NEPA)
Federal Water Pollution Control Act Amendments of 1972
Endangered Species Act of 1973
Forest and Rangelands Renewable Resources Planning Act (RPA) of 1974 (Amendments 1976)
Wildhorse and Burro Act of 1974
Archeological and Historic Preservation Act of 1974
National Forest Management Act of 1976
Federal Land Policy and Management Act of 1976 (FLPMA)
Soil and Water Resources Conservation Act of 1977
Forest and Rangeland Resources Extension Act of 1978
Public Rangelands Improvement Act of 1978

For the most part, these acts have been good for the land and animals, though occasionally their interpretation for policy has been criticized. Five Acts are particularly important when reviewing the status of southwestern rangeland productivity, the NEPA, RPA, FLPMA, Public Rangelands Improvement Act and Forest and Rangelands Resources Extension Act.

NEPA requires that federal agencies file Environmental Impact Statements for any action they might take which could significantly affect human welfare. For rangelands this played a memorable role when the Natural Resources Defense Council won its lawsuit against the

Bureau of Land Management (BLM) requiring them to file an EIS for grazing impacts, 144 in all for some 170 million acres, by 1988.

The RPA states that all rangelands be assessed each five years for their condition and productivity and that management plans be developed for all land managed by the USDA Forest Service.

Under FLPMA, Congress has established new directions, functions and goals for BLM. Congress has made clear that BLM's responsibility is permanent stewardship of the public lands under the concept of managing and conserving them for optimum public benefit (USDI 1980). The National Public Lands Advisory Council in its statement feels "because of understaffing and underfunding, the BLM has been unable to carry out these multiple-use purposes with maximum efficiency" (USDI 1980).

These three Acts, NEPA, RPA, and FLPMA, demand agency responses which require data that must be developed. However, the amount of money provided by Congress so that these agencies can respond satisfactorily is not nearly enough. The same is true for the Public Rangelands Improvement Act. The Forest and Rangelands Resources Extension Act of 1978 has been passed by Congress but it is still unfunded. As was mentioned earlier in this report, the funding of this Act would do much to meet the needs of getting current knowledge applied to the land.

Wildhorse and Burro Influences

The Wildhorse and Burro Act and its amendments require through the BLM and Forest Service that wild and free-roaming horses and burros on public lands be maintained at current inventories and that these agencies determine optimum population levels. Animals in excess should be removed. This controversial program has resulted in much rangeland abuse where the numbers of these animals have grown beyond the capacity of the land to support them. The question of how many are enough is as fundamental to wildhorses and burros as it is to livestock. The answer lies in the land resource and its condition and trend. However, the problem has been that by the time the carrying capacity of the land and its trend have been determined, the wildhorse and burro population has grown too large.

Approximately 80 percent of the 9,000 burros were in Arizona and southern California and 80 percent of the 54,000 wildhorses were in Nevada and Wyoming, as determined by the BLM in 1978. Despite the fact the issue of wildhorse and burro management is a touchy one, the land management agencies must impose strict plans to control the numbers of these animals. The kinds of population checks that are in place for other wild animals are not operative in wildhorse and burro populations.

The forthcoming reports on wildhorses and burros from the National Academy of Sciences Committee established in 1979 to study the problem will provide some important information. Especially valuable will be the Committee's recommendation for research needed to help provide answers.

Changes and Emphases Needed

The agencies responsible for public lands should define policies which are based on sound data. If the information needed is incomplete or inadequate, they should set about to collect it. Emphases should be placed on human welfare and the longterm benefits to the land and water base. Except in the cases of gross land abuse, obvious misuse or outright illegal acts, agencies should proceed with current management strategies while working with the concerned parties to implement the management actions necessary to increase rangeland productivity. It is as possible to abuse as to help land, especially arid land, with hastily conceived and improperly applied land management techniques.

Regulations or new laws must first protect the basic land resource but at the same time stabilize and preserve the ranching industry so that future options can be kept open (Box 1978). Government should and could play a more positive role for rangeland improvement rather than the currently perceived role of regulation and confusion.

Government policies should also deal better with the unique needs of the 26 million acres of Indian-owned land than has occurred in the past. Presently, this land represents some of the most overgrazed and least productive of the Southwest and the problems associated with its use are very similar to those of many of the Lesser Developed Countries of the world.

Despite the fact that the various agencies are working on inventory, condition rating and monitoring change in the rangeland resource to satisfy the Congressional Acts, there is not a single method or technique being used which is common to all the agencies. The agencies are each using a differing array of methodologies and techniques. Therefore, the data which is or will be collected on the United States rangelands will not be comparable from one agency to another. This is a serious problem which should be addressed and solved. As Box (1979) noted, "there is an urgent need to come to a single, defensible technique for measuring range condition and trend".

Yes, government has an impact on southwestern rangelands, and the Acts of Congress will continue to be wrestled with and re-interpreted until satisfactory responses can be had from the responsible agencies. In the long run, the governmental policies will be beneficial to the land--provided the financial support from Congress is forthcoming to meet the requirements of its own Acts, the agencies develop greater sensitivities to the human as well as the ecological impacts of their actions, and if the implementers of policy become more concerned with policy influence on the resource being managed than the regulations which policies inevitably foster.

Conclusions

The last to be civilized and the last to be appreciated, the southwestern rangeland is only now being recognized for its true worth. For more than a century, livestock were produced on this land with very little technological input or intensive management. One hundred years of grazing with virtually no knowledge regarding the fragile ecosystems of arid lands led to abuse in most areas of the Southwest.

Because of their early history of grazing, decades of serious brush encroachment, low and erratic precipitation and frequent extended droughts, it is thought by most ecological observers that the condition of southwestern rangelands is probably worse than the average condition of the western range as a whole.

Despite its past abuse through overgrazing and neglect, the southwestern range resource will respond positively to serious applications of technologies now available and those yet to be developed from research. In fact, the potential for improving range condition and productivity is probably greater here than for the other regions of the West. A 100 to 200 percent increase in productive capacity could result from the application of the knowledge we now have on range and livestock management practices. This increase may actually be low if Box, et al. (1977) statement is correct, that three-fourths of the western ranges are producing as less than half their potential.

If such a startling increase in production is possible with current knowledge which has been slowly accumulated by general observation and modest research efforts over the past 85 years, then the potential for production increases based on well-supported, better designed research could be even more dramatic. The current status of our knowledge will let us continue to generalize about arid land responses to various environmental pressures, but until we derive a more fundamental research base about the resource, generalizing is all that is possible.

It is important to point out that should a creditable overall program in range management be mounted for the Southwest, it should not be pointed just to the livestock industry. Even though livestock grazing is and has always been the major land use over most all the western range, it is critical to understand that the range resource is really a biological system that can, when viewed in a "systems" context, provide a variety of goods and services for the benefit of man.

It is quite understandable that the values and desires of the range livestock industry have historically influenced attitudes and land use decisions. As Wagner (1978) pointed out, stockmen, business in support of the livestock industry, and agencies which manage the one-half of the West that is public land are major components of the western economy and social milieu. But in addition to improving range productivity for livestock there are needs for the game and non-game wildlife species, the recreational potential of both public and private lands, on-site water management, as well as other less obvious needs.

The National Academy of Science's Board on Agriculture and Renewable Resources (1980) (BARR) has identified the following as a current critical issue:

> "Much of the information essential to administering public owned renewable natural resources--both terrestrial and aquatic, including marine--does not exist; and the organizational structure most conducive to expediting research to generate the information is not clear."

During 1981 the BARR will attempt to provide leadership to foster research to develop "data on inventory and assessment of renewable resources". Included in this rather broad statement on renewable resources are rangelands, and I am in agreement and am fully supportive of this declaration.

What is needed in the case of rangelands is a significant increase in both basic and applied research with the fundamental goal of improving rangeland health and productivity. There is a notable quantity of research dealing with plants, soils, and animals which is quite independent of, but related to, rangelands. Taxonomic studies of plants of a region, physiologic responses of plants to leaf removal or infiltration rates of certain soils are examples. Studies of this kind are needed which are better related to management and of a magnitude more in line with the need. Funding levels for range research nationwide are currently so low that a few broadly defined projects are all that can be sustained. Funding levels for federal agencies responsible for public range management are currently so low in relation to the enormity of the land area that superficial effort is all that is possible. Funding levels for federal and state extension programs in range management are currently so low that for the eleven western states there are only one and occasionally two range extension specialists responsible for an entire state.

When southwestern rangelands are included in the present national debate on whether the United States' agricultural productivity is declining, it seems the rangelands serve as an excellent example of a resource that is considerably below its potential. The main point of this paper is that the productive capacity of this resource could easily be doubled with proper application of current technology and further increases would be assured with increased support for rangeland research.

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Background Paper No. 9

TECHNOLOGY ISSUES IN DEVELOPING SUSTAINED AGRICULTURAL PRODUCTIVITY OF ALASKAN VIRGIN LANDS

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I. ALASKAN POTENTIAL AGRICULTURAL RESOURCES

HISTORICAL PERSPECTIVE

From the time the United States government acquired Alaska in 1867 for $7.2 million, its agricultural potential has been the subject of national conjecture--most predisposed to the idea that Alaska was a "frozen icebox" where nothing of agricultural importance could grow. Most of Alaska lies between the same latitudes as Norway, Sweden, Finland and one-third of Russia, which had a 1916 population of over 10 million, most of which existed in a largely agrarian economy. (1)

Agricultural Development

Alaska's agriculture is in the development stage and spans a wide range of enterprises ranging from local subsistence gardening to reindeer herding to the development of increased numbers of commercial farms.

Alaska contains at least 20.5 million acres of prime tillable agriculture soils and an estimated 100 million acres of range lands.(2) In 1979, there were only 310 farms producing crops on 20,432 acres, but 20,432 acres produced $9,069,000 worth of agricultural products, or $6,689,000 in farm marketing cash receipts. (3) The dollar value per Alaskan acre of the farm marketing cash receipts was $327.96 per acre as compared to $110.48 per acre for the United States as a whole. (Figure 13.)

According to the U.S. Department of Agriculture, the number of farms increased from 12 in 1900 to a peak of 623 in 1939, declining to 290 farms at the beginning of 1978. As of January, 1980, the number of Alaskan farms of 10 acres or more totaled more than 380. (4)

Dispelling the Frozen Icebox Myth: Long Photo Periods vs. Frost-Free Days

Although the number of frost-free days in an Alaskan growing season total about 100, the sun shines 20 hours per day or better during the majority of the growing season. Thus, the actual growing season is much longer and compares to such corn belt states as Illinois.

Domestic Livestock

Alaska possesses a tremendous amount of land not suitable for crops, but quite suitable for native forage for livestock. Sheep and cattle have been grazed on the Aleutian chain and Kodiak Island since Russian occupation. Although the Aleutians are no longer open for new grazing leases, cattle and sheep still exist there and have done well for decades. Total Alaskan rangeland in use as of 1978, including those state, federal and privately owned was estimated at more than 1.2 million acres. (5)

Reindeer

Between 1892 and 1902, 1,280 reindeer were imported from Siberia to the Seward Peninsula in northwestern Alaska for use as domestic livestock. By 1922, 250,000 head existed in Alaska, and by 1934, Alaska had 600,000 reindeer. The herds deteriorated due to World War II and lack of good management to a low of 25,000 animals by the 1950's and remained at about that level until just recently. (6)

PRIME AGRICULTURAL LANDS

The prime agricultural land lies mainly along the Yukon, the Tanana, the Copper, the Matanuska and Susitna River drainages. (Figure 1.) Studies indicate that there are approximately 40,000 acres of tillable soil along the Kobuk River, north of the Arctic Circle. Alaska Native villagers have successfully planted and harvested truck gardens in the area. (7) Seven hundred gardens in 35 Western Alaska villages from the Kobuk south to Dillingham were planted and harvested in 1980 under the Marston Project alone. Studies show that commercial agriculture is also a possibility in the middle Kuskokwim Valley. (7.1)

THE DELTA PROJECT

In the 1978, the State of Alaska sold agricultural rights to 60,000 acres of state land to 22 prospective farmers near Delta Junction, Alaska. (fig. 12) The State further provided low interest loans and gave the farmers two years to clear the land. As of August, 1980, 53,000 acres of land had trees and shrubs knocked down. Of that, 40,000 acres had the vegetative matter piled in berm rows to be burned and 7,000 new acres of virgin farmland stood in barley, oats and rapeseed ready for harvest. Anticipated barley production this year from the Delta project is estimated at 8-10,000 tons. (8)

In 1979, 12 varieties of oats, 26 varieties of barley, 22 of wheat and 9 varieties of green peas were tested in the Delta barley project. These varieties came from Minnesota, the Dakotas, Montana, Washington and Idaho. (8.1)

Most cold climate crops fare well in Alaska--such crops as peas, beans, squash, cabbage, lettuce, potatos, carrots, and even strawberries. Tomatoes, cucumbers and peppers work well under greenhouse conditions. The most promising large-scale commercial agricultural crops appear to be small grains, primarily barley, and canola (rape). Rape is an oil seed. The harvested seeds are crushed, the oil used in a variety of ways, in margarine, as machinery lubrication, in lotions. The remaining fiber is pressed into cakes for livestock consumption. Japan and India are principal users of rapeseed products.

In utilizing virgin lands for the Delta project and others like it around the state, farmers have not had to employ major conservation techniques, since the state of Alaska's farm lands are based on Soil Conservation Service soil surveys and include only those soils which are free of water erosion hazard, enabling maximum utilization of the land with minimum soil loss at the very beginning--a situation non-existent on farmlands in the contiguous states, where the land has been in production for generations. (8.2)

PROPOSED POINT MACKENZIE DAIRY COMPLEX

A dairy farm complex at Point MacKenzie across Cook Inlet from Anchorage is in initial stages of development, and by the end of 1981, 30 dairy farms should be allotted and underway. (9) (fig. 12)

ADDITIONAL VIRGIN LAND DEVELOPMENT IN THE TANANA VALLEY

Adjoining the Delta project in the interior just 90 miles south of Fairbanks, another 50,000 acres of State land will be added to the project. Sixty miles to the west of Fairbanks near Nenana, another 450,000 acres of State-selected land awaits Federal land ownership transfer to the State as part of the State's inheritance under the 1959 Statehood Act. On this, too, the State plans to allocate agricultural rights. (10)

SMALL-SCALE AND SUBSISTENCE FARMING

In addition the state legislature appropriated funds to initiate small-scale and subsistence agricultural projects in bush areas of Alaska. (11)

The Marston Project

On the Kobuk River, the Marston Project, an agricultural project sponsored by the Marston Foundation and Brigham Young University, Alaska Native villagers are producing garden crops such as rhubarb cabbage, potatos and greenhouse tomatos, cucumbers and peppers. (fig. 12) One enterprising person grew--and harvested--corn north of the Arctic circle. Marston Project officials feel that commercial agriculture is feasible on the 40,000 acres of identified agricultural soil in the Kobuk River valley, and plan to ship the produce to Kotzebue and other villages by boat down the Kobuk River, provided environmental regulations for the Kobuk Valley National Monument do not preclude additional motorized commercial boat traffic. (12)

II. CONSTRAINTS ON DEVELOPMENT

IMPORTED FOODS LESS EXPENSIVE

In spite of the fact that Alaska has many potential acres of agricultural land, some 90 to 95 percent of the Alaskan food supply is imported, even those items that can be easily and economically produced within the state. This is principally due to a lack of marketing and distribution structure to accommodate locally-produced items. Additionally, the sparse population spread over a far-flung area (approximately 400,000 people in 586,000 square miles) contributes to the problems of providing an effective transportation and distribution network. Storage, processing, and secondary and tertiary manufacturing and production processes are either small or entirely absent.

The few agricultural transportation corridors available in Alaska with only the exception of the Matanuska Valley, do not reach major Alaskan agricultural areas. However, the existing transportation systems do reach the major urban areas from outside the state to date, providing lower-cost foods at lower freight costs.

HIGH COST OF TRANSPORTATION, UTILITIES AND FARM EQUIPMENT

In developing agriculture on Alaska's virgin lands, farmers, ranchers and herders encounter many problems not found in areas where agriculture is aready established and transportation systems easily accessible. The cost of heavy clearing equipment and farm implements shipped from the "lower-48" is staggering. Construction materials and labor costs are high, as is seed and fertilizer. Power generation in newly developed or proposed agricultural complexes is minimal or non-existant, as are telephone communications and utilities in many areas.

LIMITED TRANSPORTATION FACILITIES

Rail and highway facilities in Alaska are limited. The Alaska Railroad extends from Fairbanks to Seward in one main line, and with the exception of the long established agricultural Matanuska-Susitna valley district, does not serve Alaska's present agricultural areas. While linking it to the Canadian railroad--and thus the continental rail system--has been much discussed, carrying out the idea remains in the future. There are less than 5,000 miles of roads in all of Alaska with less than 1/3 of them paved, and most of the paved arteries link--or are contained in--the major urban centers of Fairbanks and Anchorage.(13)

INADEQUATE MARKETING INFRASTRUCTURE

Alaskan marketing systems are non-existent or not yet equipped for dealing in agricultural commodities. Delta is 60 miles from the railhead in Fairbanks and the Alaska Railroad is not adequately equipped to handle agricultural production from that area. At present, crop production from the Delta area does not justify the Alaska Railroad expending the monies necessary to add a spur from the nearest marketing center, Fairbanks, to Delta for example, or purchase the additional railcars and other equipment to ship the Delta crop production from the field to the nearest deep water port for shipment to market. (14)

EXPORT MARKETS--ARE THEY COST-EFFECTIVE?

Alaskan grain has found a ready market in Asia, but the grain must be shipped in large enough lots from a sea port to be economically feasible. Under existing Alaskan transportation tariffs and market access, Delta project grain is estimated to cost $180.00 per ton f.o.b. the Asian market. The current (Summer, 1980) world market price on barley averages around $122 to $130 per ton. Since it currently costs more to ship Alaskan barley to the Asian market than selling price per ton, Alaskan grain would presently be hard-pressed in the Asian market.

DEVELOPING EXPORT AND DOMESTIC MARKETS FOR REINDEER PRODUCTS

The reindeer industry provides meat to northwest Alaskan residents and reindeer horn has brought upwards of $80 per pound on the Asian market. Lack of veterinary services and facilities, modern herd management techniques and uncertain range leasing arrangements, as well as remote herd location, have hindered Native herders from realizing full potential from their herds.

In addition to economics, transportation and geographical distance from major marketing centers, Alaska's agricultural future depends in great part on Federal land laws and regulation, as well as expanding agricultural research and educational outreach within Alaska.

PATCHWORK LAND OWNERSHIP IN ALASKA

Most of Alaska--92%--is still in the Federal domain. The area richest in agricultural soils in the state is the Yukon Flats area now part of the Yukon Flats National

Monument, which--with the attendent managing agency environmental regulations--preclude or negate any prior claim by the State to title or possibly any future agricultural development. More than 50 percent of Alaska's agricultural cropable soils lie within Federal lands withdrawn for national parks and wildlife areas. (15)

Alaska's patchwork land ownership with State and private lands surrounded by Federal land plays a great part in how Alaskan agriculture may or may not develop. (figs. 2-5) The most important problems Alaskan agricultural interests will have to deal with in new lands management are those combinations of land and environmental laws and regulations which hinder or preclude the further development of viable economical Alaskan transportation and marketing systems. Given time and opportunity, based on previous production growth rates, Alaskan agriculture will take its place in the world market, provided present external constraints are resolved.

III. CONVENTIONAL AGRICULTURAL TECHNOLOGIES

AGRICULTURAL TECHNOLOGIES ADAPTABLE TO ALASKA

Since crop production in Alaska involves unique soil and climate conditions and long summer daylight hours in comparison with other states, it is frequently impossible to transfer directly to Alaska the results of crop production research carried out by other universities at lower latitudes.

The technologies of large grain farm agriculture, confined livestock housing, greenhouse operation and other on-going U.S. agricultural enterprises fit the Alaskan situation with limited, if any, modification. However, most of the lower-48 virgin agricultural lands were cleared by man, oxen, horse, and mule power, not 400 horsepower four-wheel-drive tractors or D-9 caterpillars. For these technologies, Alaska must look to such places as the Peace River country of Canada. The Peace River region is the closest physiologically to Alaska's developing agriculture and already has the market and research infrastructure in place. No place else in the United States are reindeer and musk-oxen commercially raised (in fact, the world for musk-oxen), so these technologies may--in part--be borrowed from Eurasia, but--by and large--must be developed here in Alaska.

MODERN TECHNOLOGY VS. ENVIRONMENTAL LAW

The issues of modern agricultural technologies as they relate to the national body of environmental law and regulation are much more significant than the above physical and knowledge-based issues. The national system is geared to correcting past errors in judgment relative to the development of America's natural resources, in an environment of man-caused pollution levels. Thus, the easy way out is simply to allow no more pollution above given minimum levels. In Alaska, the rivers and air carry silt and dust levels above U.S. minimums at certain times of the year--all of which Mother Nature generates due to glaciation, causing bank erosion, stream siltation and natural air pollution. The result precludes development of heretofore undeveloped agricultural resources, since in Alaska there is nothing that can be "cleaned up" to offset even the slightest increase in particulate matter--which is inevitable due to unpaved roads and in some instances, possible air or stream-born particles from fields.

PESTICIDES AND ARCTIC RESEARCH

Pesticide use in Alaska is at levels far below the agricultural areas of the "lower-48" due to Alaska's natural climatic pest controls, plus new lands and good cultural practices which prevent problem development. Where we do need certain agricultural chemicals, we have major problems in applying pesticides to certain crops, primarily canola (rape). This crop, long grown in Canada, is a minor crop for the U.S. and consequently not listed as a crop approved for pesticide application in this country.

Alaska faces major problems in developing effective weed control for expanded agricultural production. The agricultural development now underway will not be economically viable if reliable and safe weed control procedures are not developed to permit Alaskan farmers to compete with farmers elsewhere. Alaska currently has no weed scientist employed by any state or federal agency, or by the private sector in Alaska to participate in integrated pest management. Integrated pest management involves the development of combinations of technological and biological controls to reduce crop losses from weeds, insects and diseases. Federal law requires well designed, controlled and statistically valid research to obtain data on which to base maximum levels of weed, disease and insect controlling chemicals mandated by the Federal Insecticide, Fungicide and Rodenticide Act of 1972 (16)

We have a similar problem with our reindeer industry where certain insect pests are a problem. The insects are eliminated from cattle through the use of certain insecticides which also work well in reindeer. Again, reindeer are not listed as an approved use of the insecticide. Although herd owners have been given temporary use permits for some insecticides used with cattle, they must wait a year after insecticides are applied to reindeer before the animals are slaughtered for human consumption.

IV. VIRGIN LANDS DEVELOPMENT IN ALASKA

What makes virgin lands development in Alaska so unique? Resource analysis and planned development.

STATE AGRICULTURAL DEVELOPMENT STRATEGY

Alaska has adopted specific plans for the development of agriculture over the next five year period. In 1976, the Alaska state legislature enacted legislation requiring the classification for agricultural use of approximately 650,000 acres of state patented or tentively-approved lands. In 1978, the state sold 65,000 acres of this land near Delta Junction in the Tanana Valley and 3,000 acres on the lower Kenai Peninsula for agricultural use. Contracts were signed to clear the land for cropping and commercial production of barley and rapeseed was underway by 1980. Also constructed in 1980 was a 6,000-ton grain elevator at Delta Junction and the deep water port of Valdez agreed to construct grain storage facilities. (17)

Financing

The state of Alaska has committed over $15 million in financing for agricultural production, processing and marketing to initiate the agricultural development demonstration project near Delta Junction. The state is also engaged in a study of the entire Susitna basin in southcental Alaska and the Tanana-upper Yukon area in interior Alaska in cooperation with Federal agencies. These studies place substantial emphasis on agriculture. This project will be expanded on adjacent land to place 200,000 acres in production by 1985 to support the transportation and marketing system required for Alaskan commodities. Plans are also underway to place an additional 320,000 acres of land in production near Nenana in the Tanana Valley by 1990. Other planned sales of state land for agricultural use include 11,000 acres in the Talkeetna area and 15,000 acres near MacKenzie Point north of Anchorage. The scope of these commitments is evident in that only about 20,000 acres are currently under cultivation in Alaska. (18)

Farm Land Sales Criteria and Agricultural Rights

A lottery system is used on large-block project land sales. In the past, to qualify for the lottery pool, an individual had to possess $35,000 in equity capital, show evidence of management background, be a resident of Alaska for 30 days and a U.S. citizen. Corporations were excluded.

Title on all State lands sold for agricultural uses in Alaska is for agricultural rights only. Subsurface rights and all other development rights are retained by the State. Thus the farmer and the land are protected from land price increases based on other uses or nonagricultural speculation.

Reindeer Range Surveys--A Cooperative Effort

At the request of Native associations, federal agencies have completed surveys of 2 million acres of reindeer rangeland in western Alaska and are in the process of completing an additional 2 million acres. These surveys are designed for use in developing grazing systems that will facilitate sound management of Alaska's reindeer range, provided other external regulatory and legislative restraints are resolved.

Small-Scale and Subsistence Farm Development

Alaska Natives are currently receiving title to their lands, including prime agricultural lands, and research will be required to aid in developing and bringing into production some of those lands to assist in food production and to generate revenues for approaching taxation of those lands. The 1979 session of the Alaska state legislature appropriated more than $500,000 to initiate small-scale and subsistence agricultural projects in bush areas of Alaska.

Economic Development Goals

A program for power and economic development published in 1978 by the Alaska Department of Commerce and Economic Development and approved by the Governor of Alaska includes implementation of the following near-term targets for agriculture:

- Continued agricultural expansion near Delta Junction, Alaska.

- Develop an expanded greenhouse industry in Alaska utilizing surplus industrial heat.

- Develop programs to enhance reindeer production in Alaska.

- Continue industry promotion for the production of barley and rapeseed for local and export market.

Alaska Renewable Resources Corporation

In 1978, the state created the Alaska Renewable Resources Corporation to assist in the development of renewable resources including agriculture. That same year, the Commercial Fishing and Agricultural Bank was established to provide financing for Alaska's agricultual and fishing businesses. In 1979, the Alaska State Legislature increased the limits of the agricultural revolving loan fund administered by the Alaska Division of Agriculture to provide increased financing for agricultural production.

INADEQUATE ALASKAN RESEARCH CAPABILITIES

Cropland development in Alaska for the past decade or two has been primarily a State-initiated effort. (Grazing lands, to be discussed later, are primarily Federal lands.) The process typically has been a resource analysis, public involvement and resource allocation effort following good land use practices which, recognize the variety of resource and sociological uses of land.

AGRICULTURAL SOIL SURVEYS IN ALASKA

Agricultural areas are initially identified from the U.S. Soil Conservation Service's "Exploratory Soil Survey of Alaska" printed in 1979, but available since field work was completed in 1973. (19) Some areas have detailed soil surveys with others undergoing detailed surveys currently. The Delta area, for example, was surveyed in 1963 through

1967. (20) The expansion of the project will be on soils surveyed during 1979.

The use of detailed soil surveys allows the state to retain in state ownership soils which have erosion hazards for shelter belts, wildlife habitat, public recreation areas, etc. The State then released only the best agricultural soils (Class II and some Class III soils) which have no water erosion potential for agricultural development. As previously mentioned, the State transfers only the agricultural rights to the land, thereby preventing subdivision and sale of the land for other than agricultural purposes.

PROBLEMS WITH THE CURRENT SOIL SURVEY SYSTEM

Soils are classified according to certain arbitrary criteria set forth in the final Rules for Unique and Prime Farmlands set forth in the Federal Register. The criteria by which Class I soils are determined according to average soil temperatures prevents Alaska's agricultural soil from being classified as Class I soils--which in reality--most Class II and some Class III actually are. With the soil temperature specifications of an average of at least 32 degrees Fahrenheit and a summer average minimum temperature of 47 Degrees Alaska's agricultural land cannot qualify as Class I. This temperature criteria of soils has only limited influence on growth rates of adapted crops and doesn't take into consideration the full complement of growth factors.

Some of these growth factors such as long daylight hours and low evaporation-transperation rates more than offset the low soil temperatures for adapted crops. Attempts to modify the classification criteria for Alaska have been unsuccessful thus far.

AGRICULTURAL SOIL EROSION PREVENTION TECHNOLOGIES

Technologies relative to wind erosion are the only erosion negating practices we must concern ourselves with. Minimum tillage, strip cropping, shelter belts and windbreaks are all important technologies, since most of our agricultural soils are of wind-deposited origin. In addition, the above practices are important from a snow managment standpoint to provide moisture to the following season's crops.

Of special note here is the relatively small amount of moisture required to produce a crop in Alaska's interior agricultural areas. This is a result of two major conditions, 1) low evaporation/ transperation (loss of water from the plants) due to cool temperatures, and 2) permafrost (permanently frozen ground) near the surface, which holds what moisture occurs within the root zone so that plants may utilize it.

GRAZING LANDS TECHNOLOGIES AND SOCIOLOGICAL CONSTRAINTS

Grazing lands fall into three general sub-categories: 1) Reindeer, muskoxen, bison, 2) domestic livestock (sheep, cattle, horses, etc.), and 3) wildlife. The latter two won't be dealt with in detail. (21)

Reindeer and muskox husbandry are likely to become major agricultural industries in western Alaska. Potential range is expansive, running from the northwest side of the Alaska Peninsula, northward in a band up to 100-150 miles inland from the coast to the Brooks Range, then eastward encompassing the entire North Slope. In general, muskox ranges are more closely associated with the coast. (22)

At the present time, society's judgement of the highest and best use of the majority of the above area is for other than reindeer or muskox range. In recognition of this, plus management problems associated with caribou pirating reindeer herds or parts thereof, the Seward Peninsula emerges as having the least confiicts, since the Seward Peninsula is not within current caribou migration routes. The caribou is a totally wild animal, but genetically very closely related to the domestic reindeer. When caribou migrate through a reindeer range, the reindeer are assimilated into a caribou herd and migrate out with them. Therefore, major reindeer and muskox grazing is likely to be limited to the Seward Peninsula. In addition to the peninsula, the islands west of Unimak in the Aleutian chain and off the west coast in general, have excellent potential, but for the most part, are federally restricted. (23)

SATELLITE IMAGERY UTILIZATION FOR RANGE SURVEYS

Reconnaissance-level soil survey data is available for the northern part of the Seward Peninsula. This level of survey provides all the necessary information needed for determining stocking rates and seasonal use. Reconnaissance-level data could be generated for the remainder of the Peninsula at reasonable cost of both capital and manpower, since the first survey developed a technique utilizing satellite imagery for tundra range surveys, which speeds the process. (24)

NON-INDIGENOUS PROTECTED SPECIES VS. AGRICULTURAL DEVELOPMENT

Bison are a proven "domestic" livestock in many areas of the northern Great Plains and mountain states. The result is that the potential bison industry's major problems do not revolve around technology issues, but around sociopolitical issues of land availability and the idealized role the bison played in America's past history. (25) Bison were moved to the Delta area in 1923 and these non-indigenous creatures are covered by the Endangered Species Act. History shows that bison can be cross-bred with cattle for meat production, but bison within Alaska may not be used for this purpose. In addition, their habitat transgresses the Delta project, endangering grain crops. (Figure 11) There are, however, major range areas along the north side of the Alaska Range which could support bison with few conflicts.

AGRICULTURAL ENGINEERING TECHNOLOGY
ADAPTED FOR ALASKA

Enclosed Animal Housing

Sub-zero winter temperatures in Alaska demand enclosed livestock housing that is energy-efficient and moisture-free. Because a great amount of moisture is generated by enclosed farm animals, steps must be taken to insure that enclosed animal housing is well-ventilated and at the same time well-insulated and warm enough to withstand long periods of sub-zero temperatures. Adequate farm structures encompassing those factors require on-going agricultural engineering technology to meet the demand for farm facilities appropriate for Alaska.

Unique Alaskan farm facilities, enclosed swine and dairy barns, as well as vegetable and grain storage facilities have been built within the state during the past few years, that demonstrate an engineering technological advancement that could be utilized in the northern tier contiguous states, as well as northern countries throughout the world. For many years, the only agricultural engineer with this particular expertise within the state was with Cooperative Extension Service but has recently retired and presently no funds exist with which to place another in that position. The Alaska agricultural industry will need this particular type of agricultural engineering expertise and on-going research if cost-effective, energy efficient, safe farm structures and human housing are to continue to be built.

Mobile Slaughter Facilities for Reindeer Harvest

Utilization of Alaska's virgin agricultural lands for grazing purposes may depend to a large extent on very high technology inputs (satellite imagery to do range surveys) forming a base to use long established range managment technologies which have been with us for many decades elsewhere in the world.

Marketing of products from Alaska's range lands may require a new look at existing regulations and existing technologies, both of which are interdependent and quite probably inappropriate to Alaska. Slaughter facilities for inspection purposes may well be inappropriate for the Alaskan environment. The energy needed for construction and maintenance of above-freezing water temperature because of water needs, the degradation of surrounding ranges since overland shipment of animals is impossible, and the problem of large volumes of waste disposal under arctic conditions, all suggest the need for a better way. An alternative which has existing technologies in place but lacks regulative credence is field slaughtering where animals are slaughtered out on the range during Alaska's long winters on top of the snow.

Another alternative for field slaughtering is a portable enclosed slaughter facility that could be transported to the field, perhaps by air, utilized and moved to other field sites as reindeer harvests continue. Inedible waste parts of the reindeer could be stored outdoors during the winter in closed containers and later processed and utilized as fertilizer.

ALTERNATIVE TECHNOLOGIES

Wind Energy

Natural wind conditions exist in the Delta area for utilization of wind power mechanisms to generate electricity for farm use, augmented by diesel or steam-fired generators, perhaps providing a lower-cost alternative to electrical generation and dissemination by conventional methods.

Waste Heat Utilization for Greenhouse Production

Enough waste heat and power is generated from the oil pipeline pump stations to sustain a year-round greenhouse agricultural industry. While the retrofit capability necessary to adapt this waste heat is currently not cost-effective, that capability could be incorporated into natural gas pipeline pump stations while they are being built.

Geothermal Energy

Geothermal energy abounds within Alaska. But except where it is currently in use, geothermal energy may not be utilized on nearly all federal land in Alaska due to environmental regulatory restriction. Geothermal energy has provided heat and power generation in Greenland for generations, and a large amount of Greenlandic produce comes from greenhouses heated and powered by geothermal energy.

A pilot geothermal-powered greenhouse project is underway at Pilgrim Hot Springs on the Seward Peninsula, and Circle Hot Springs north of Fairbanks has enjoyed a geothermal heated greenhouse for many decades.

In coastal communities where driftwood accumulates in abundance, perhaps wood-fired generators and stoves could be used to heat and power greenhouses, although this technique has not be utilized in measurable quantities.

Self-Contained Livestock-Feed Technologies

Subsistence farming pilot projects may develop certain technologies that could be used in other circumpolar sub-arctic regions. For example, in areas where fish are abundant, hogs are being raised on fish and finished off with barley or rye grown specifically for feed.

V. AGENCY AND CONGRESSIONAL RESTRAINTS

How They Influence Development on Alaska's Virgin Lands

Alaska's Federal land currently enjoys extremely changeable land management and classification status. It is managed under many land planning and environmental laws, such as the National Environmental Policy Act of 1969, Section 4 (f) of the Department of Transportation Act of 1966, the Endangered Species Act of 1973, the Clean Air Act, Clean Water Act, the Federal Land Policy and Management Act of 1976, the Wild and Scenic Rivers Act, the Wilderness Act, the International Migratory Bird Treaty, Coastal Zone Management Act and the International Caribou Treaty. (26)

In addition, where federal lands are classified within the National Park System, Wildlife Refuge System, Forest, Wild and Scenic Rivers or Wilderness System, these lands and the bordering non-federal lands may be managed under the regulations pertaining to those systems. (27)

Where non-classified federal land falls within the management of the Bureau of Land Management, those lands are managed under the mandates of the Federal Land Management and Policy Act.

Alaska also has 56 million acres of national monuments created in 1978 under the Antiquities Act of 1906. Two of these monuments are Fish and Wildlife monuments which is a classification never before made in the history of the National Preservation system. This is in addition to the 6.9 million acres of national parks and monuments that existed in Alaska prior to 1978. (28)

Energy

The high cost of fuel adds to the inflated cost of farming within Alaska. The high fuel costs are due partly to deregulation and partly to the fact that only one petrochemical facility exists that produces gasoline and diesel fuel, located on the Kenai Peninsula. The North Pole Refinery near the Delta project produces home heating fuel for local consumption only, and aviation fuel for airline consumption. In addition, gasoline quotas that have been imposed on states on a per capita basis are far more stringent within Alaska than in other states. Farm machinery is not produced within Alaska and must be bought in the lower-48 states and shipped into Alaska. As a result barley grown on the Delta project costs an average of $124.10 per acre to produce. Assuming a yield of 1.5 tons per acre, median cost per ton to produce barley approached $80 or more. (29)

Buffer Zones

While a great part of the state's agricultural land currently in production is not within or surrounded by federal land, it does fall within the "buffer zone" adjacent to federal lands.

Visibility Requirements

The Environmental Protection Agency has determined that visibility regulations under the Clean Air Act should cover not only the view looking into, or within a Class I area, but also the view looking out from inside the area, thus affecting agricultural production in State land in buffer zones adjacent to pre-existing National parks, monuments, etc. (30)

Surrounded by Federal Classified Lands (Yukon Flats)

The state selections within the Yukon Flats were made primarily for their agricultural potential. Some of those lands have also been selected by Alaska Natives as part of their Alaska Native Claims Settlement Act entitlement. While the state may not receive its selections, the Alaska Natives probably will, and any subsequent agriculture they may wish to develop will be subject to the environs of those laws and regulations governing the surrounding monument--even though Native selections will be private lands. (Figures 8 - 10)

Adjacent to Federal Classified Lands

Nenana and the Point MacKenzie Project

The agricultural development scheduled for the Nenana area could well be governed by the laws and regulations of the Denali Monument and Mt. McKinley National Park. The Point MacKenzie project falls under the jurisdiction of the Coastal Zone Management Act. (31) In addition, it has already been delayed by Section 404 of the Federal Water Pollution Control Act which requires dredge and fill permits issued at the discretion of the Army Corps of Engineers.

This requires, among other things, the preparation of an environmental impact statement. (32)

The Delta Project

The Delta Project abuts a military reservation and Bureau of Land Management lands. Under Section 603 of the Federal Land Policy and Management Act, the Bureau of Land Management must conduct a wilderness review of all unreserved lands of 5,000 acres or more. This process has barely begun within Alaska. Until this process is complete, BLM-managed lands must be managed as wilderness, precluding development of that land. Any lands abutting BLM lands may also be subject to the mandates of Section 603 of FLPMA. (33)

Constraints on Transportation

In addition, Federal aid to states for public roads, railroads and other public facilities has been cut back with Alaska greatly over the past year. If any new road, rail or air facilities are to be initiated, or existing transportation facilities maintained or improved, the funding may well have to come primarily from the state in the future.

Waterfowl vs. Agriculture

Alaska is haven for a variety of fowl that come under the International Migratory Bird Treaty and/or Endangered

Species Act. In the case of migratory birds, particularly ducks and geese, a major concentration within Alaska occurs within the Yukon Flats monument, where, incidently, the highest concentration of prime agricultural soils also occurs. While agricultural development appears to be effectively precluded in that area, studies show that the highest concentration of ducks and geese within the continental U.S and Canada are also the areas of highest grain production. (34)(Figures 6 - 8)

Reindeer Grazing on Federal Leases

Reindeer grazing is conducted primarily on federal leased land. Previous to utilizing the Antiquities Act within Alaska, reindeer herders operated on 15 year leases from the Bureau of Land Management. Since 1978, reindeer herders' leases within the Bering Land Bridge National Monument and the Selawik withdrawal have been made on a temporary yearly basis, subject to revocation by either the National Park Service (Bering) or Selawik (BLM), thereby rendering the entire reindeer industry tenuous, at best. (35)

Reindeer Management vs. Environmental Integrity

Reindeer are herded by a combination of aircraft and ORV--either snowmobile or track or "tundra-tired" vehicles, on foot or with dogs. Federal Aviation Administration regulations preclude flying lower than 1,000 feet over national parks, monuments or refuges except for emergency purposes or for landing at designated landing areas, subject to the discretion of the superintendent of the particular area. While some studies show that surface damage from ORVs is irreparable, personal field studies show that where overland vehicles disturb the indigenous vegetation, willow sprang up to replace it, providing an effective insulative and erosion-preventative ground cover. (36)

Shifting Land Classifications

The constant shifting land classification and land management status has, in part, affected the agricultural development within Alaska. Alaska Natives are still in the process of receiving their lands under the Alaska Native Claims Settlement Act. As of October 1978, they had received patent title to a little over 100,000 of the 40 million acres due, thus placing much of their renewable resource land management plans in a holding pattern.

In 1980, the state of Alaska had received title to 32 million acres of its 103.5 million acre entitlement under the 1959 Statehood Act, lands with which--according to the Act--"to form an economic base." The lands the state selected were made primarily on the basis of multiple use-sustained yield renewable resource potential, to establish a long-term sustainable economic base, rather than a "boom or bust" economy generated by intensive harvesting of non-renewable resources such as hard-rock minerals or petroleum.

Inadequate Funding for Alaskan Agricultural Research

Agricultural Engineering

Research on agricultural engineering is essential in solving problems involving the use of agricultural equipment, tillage practices, soil conservation procedures and water management for irrigation where needed. At present, there is no agricultural engineering program, including soil conservation engineering in interior Alaska. Research on conservation tillage practices to protect the soil from wind and water erosion must be developed for the soil and climatic conditions in interior Alaska. Requirements outlined in the Federal Water Pollution Control Act of 1971 to develop best management practices for pollution control from agricultural land mandate that these practices be established and the research be done. And yet, funding for such vital research entities as the USDA agricultural experiment stations continues to be cut back within Alaska. Failure to develop appropriate practices will very likely lead to violations of the Federal Clean Air Act and Clean Water Act and could jeopardize the entire development of Alaska's agricultural soils.

Crop Ecology

Research needs in crop ecology, including soil fertility and management resulting from the clearing and breaking of thousands of acres of new land for agricultural production in Alaska have expanded substantially beyond existing Alaskan research programs. New lands are being brought into production for which there are no previous production data, soil fertility data, or soil test calibration data. Research results to meet those needs cannot be transferred to Alaska from growing conditions of other states. If research in crop ecology and soil fertility is not expanded on newly developed agricultural projects and those proposed, it is likely that mistakes in crop varieties, planting dates, fertilizer rates and soil management practices will reduce farm profits substantially. Preliminary calculations based on 1978 fertilizer prices indicate that a 20% overuse of nitrogen, phosphorus and potassium fertilizers on 60,000 acres of new land in Delta Junction, for instance, would result in a loss of almost $1 million to the project farmers. This would be particularly damaging when positive returns to capital are critically needed during the initial stages of new lands development. (37)

VI. ALASKAN VIRGIN LANDS AGRICULTURAL DEVELOPMENT: ITS PLACE IN THE WORLD FOOD MARKET

Virgin Land Development In Other Countries

While U.S. surplus does not create a demand for Alaskan agricultural products on the national market, increasing world food demands plus the shrinking number of agricultural acres per capita in the United States almost mandate that Alaska participate in the world market.

Just to maintain the per-capita level of food consumption in the world that we have today, We will have to produce twice as much food in the world in the next 30 years. Other countries are beginning to move in the same direction that Alaska is agriculturally.

Japan invested $138 million dollars in three Brazilian agricultural projects, including $25 million for land development, $50 million for cooperative credit and loans and $63 million for a transportation system. In turn, 100,000 acres will be developed and by 1983, they expect to produce 100,000 tons of grain and oil seeds from that 100,000 acres. If that 100,000 acre project succeeds, they plan to have 1 million acres in production in Brazil in the next 10 years. (38)

Sustained Alaskan Agricultural Development Depends On Cooperative Effort

For the near term, agricultural development on Alaska's virgin lands and the necessary technologies to sustain that agriculture are still in the embryo stage. But for the long-term, provided external restraints are resolved, Alaska's virgin lands can sustain a substantial agricultural productivity and provide a sound economic base for Alaska.

Alaska's virgin agricultural lands places the state in a unique position. Worldwide urban pressures, increased food consumption, increased population and better diets make Alaska one of the few places were vast acreages of virgin potential agricultural land still exist. Alaska must look to world markets for selling its agricultual products, and it must react to the worldwide demand for agricultural products. Economically, it may not be feasible to produce certain products in parts of Alaska at this time. In a very few years, however, the question will not be "is it economical to produce food," but, "whether we can produce food here." Increasing demand will probably make it economically feasible. (39)

Alaska's future agricultural development depends almost entirely on virgin lands. Agricultural research, soil classification guidelines and systems, environmental laws and regulations, and state, local, federal and private land managing agencies will have to work together and make regulatory and monitoring modifications where necesary to ensure the orderly, environmentally safe and technologically sound development of Alaska's agriculture. Vegetable and livestock produce for local consumption, as well as subsistence farming will remain a vital part of the agricultural system. But the future agricultural demands will be met, in large part, by family-owned agribusiness if Alaska is to participate in the world market. (40)

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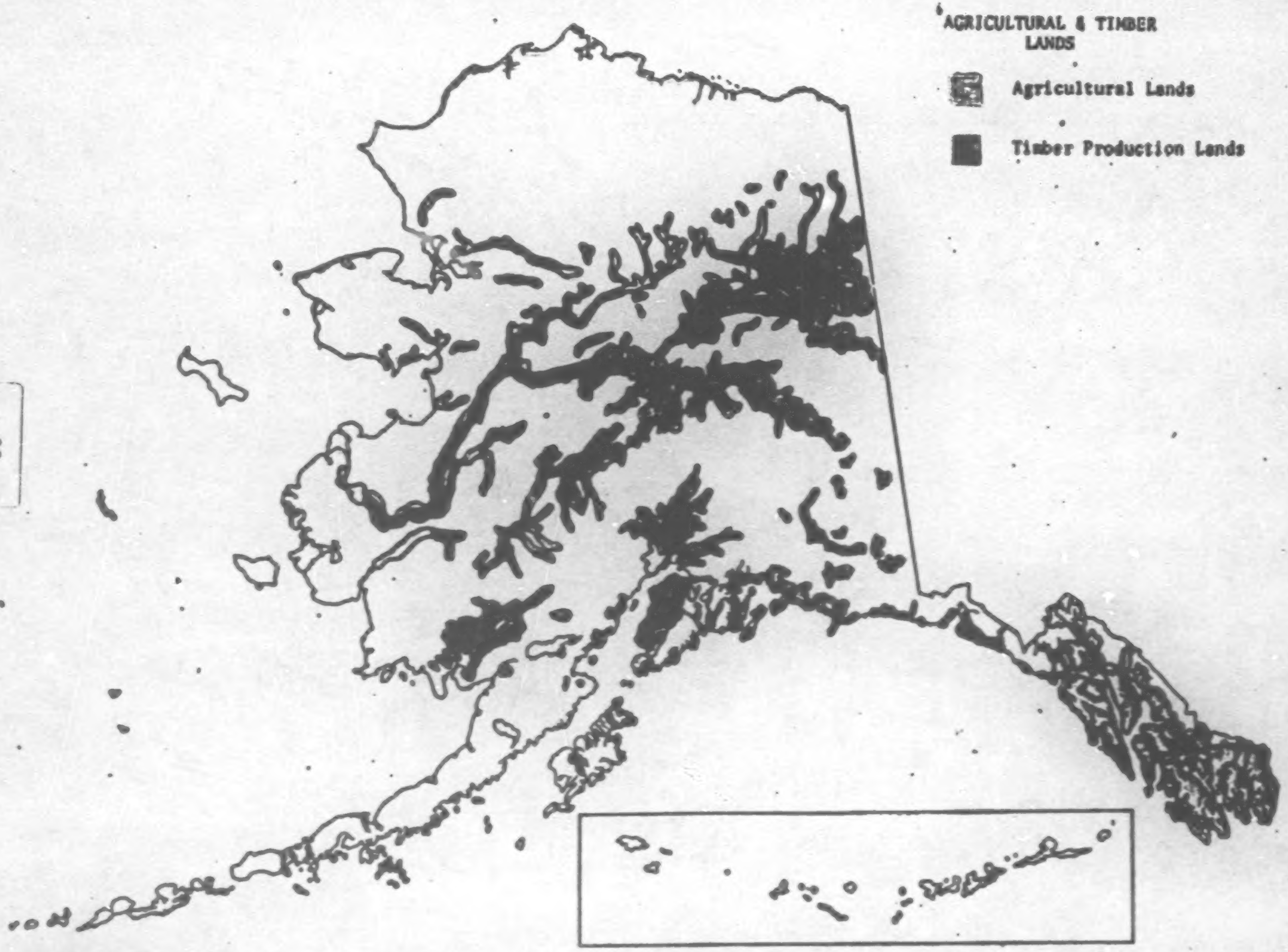

AGRICULTURAL & TIMBER LANDS
Agricultural Lands
Timber Production Lands

Figure 1.

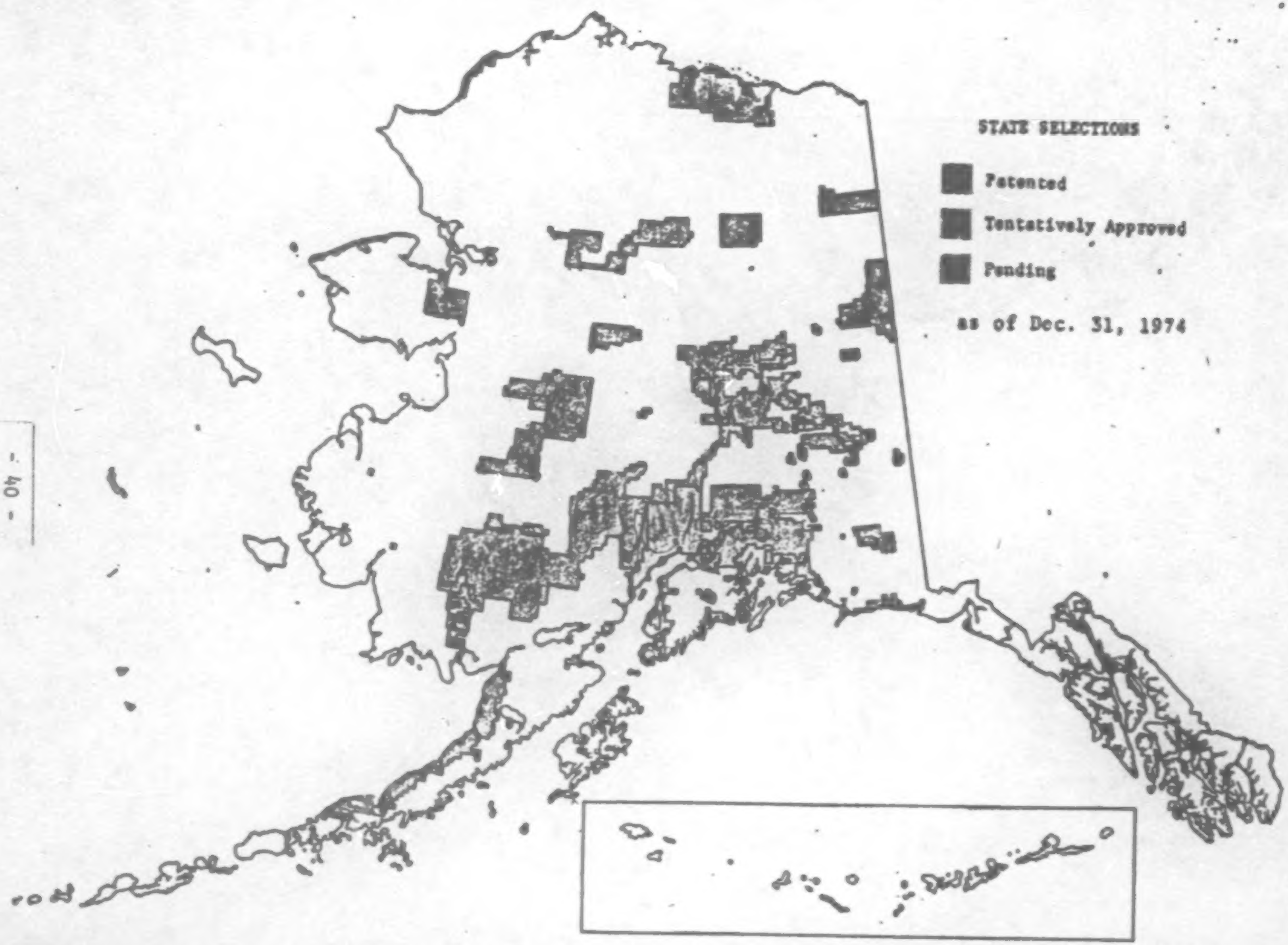

STATE SELECTIONS
▨ Patented
▨ Tentatively Approved
▨ Pending
as of Dec. 31, 1974

Figure 2

NATIONAL MONUMENT PROCLAMATIONS

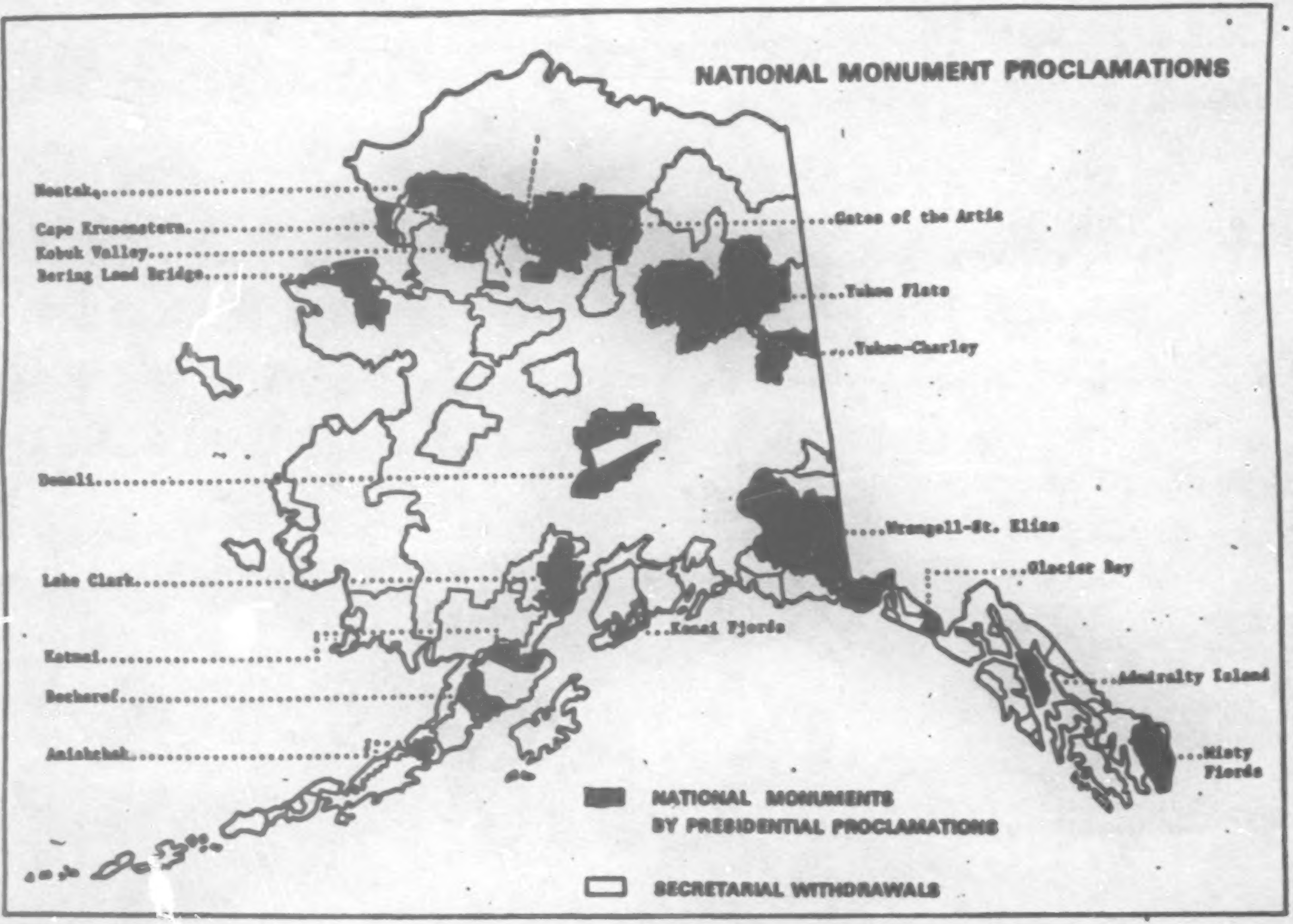


FIGURE 3.

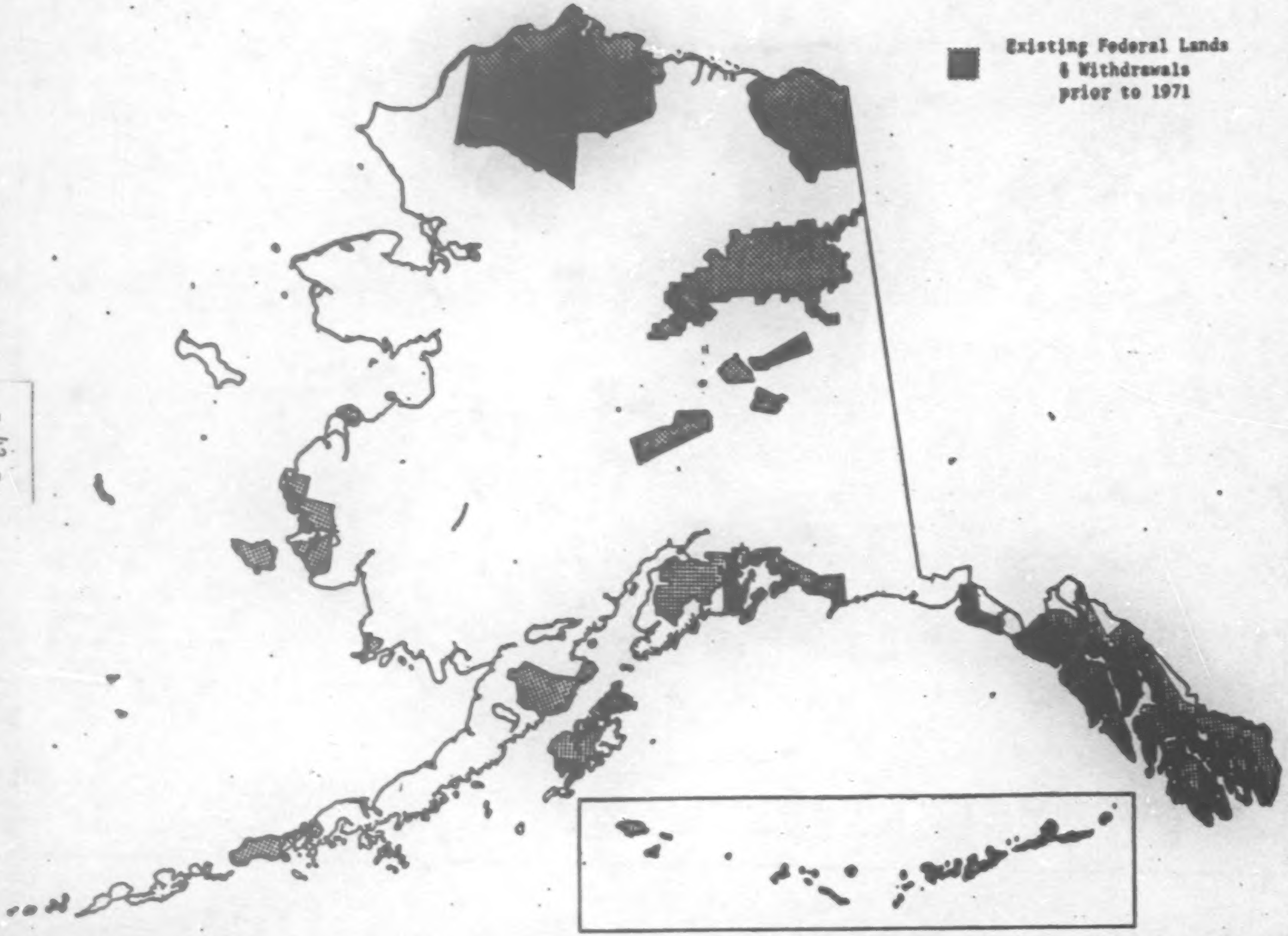


Figure 4

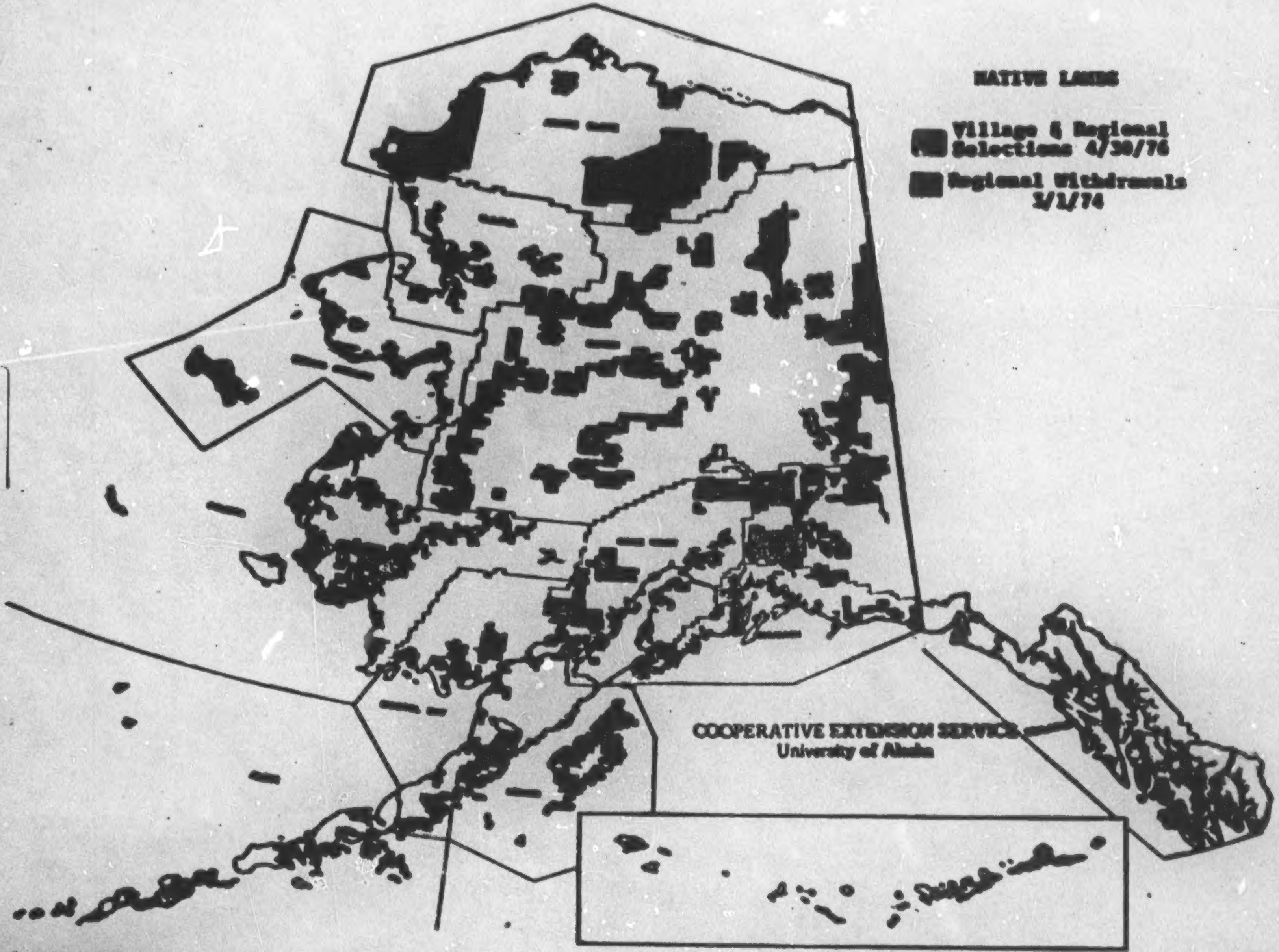
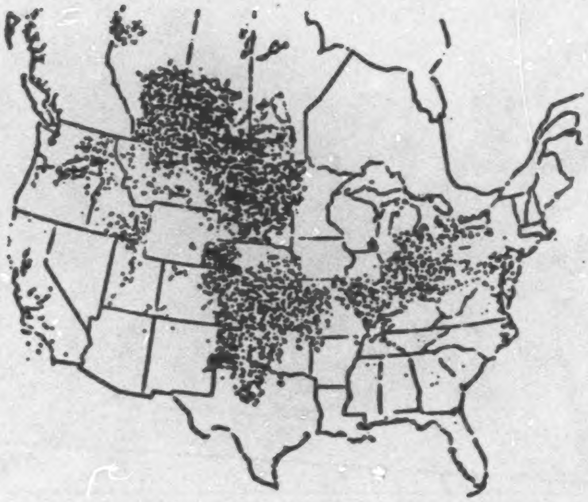

NATIVE LANDS
Village & Regional Selections 4/30/76
Regional Withdrawals 3/1/74
COOPERATIVE EXTENSION SERVICE
University of Alaska

FIGURE 5.

DISTRIBUTION OF WHEAT ACREAGE IN THE UNITED STATES AND CANADA *

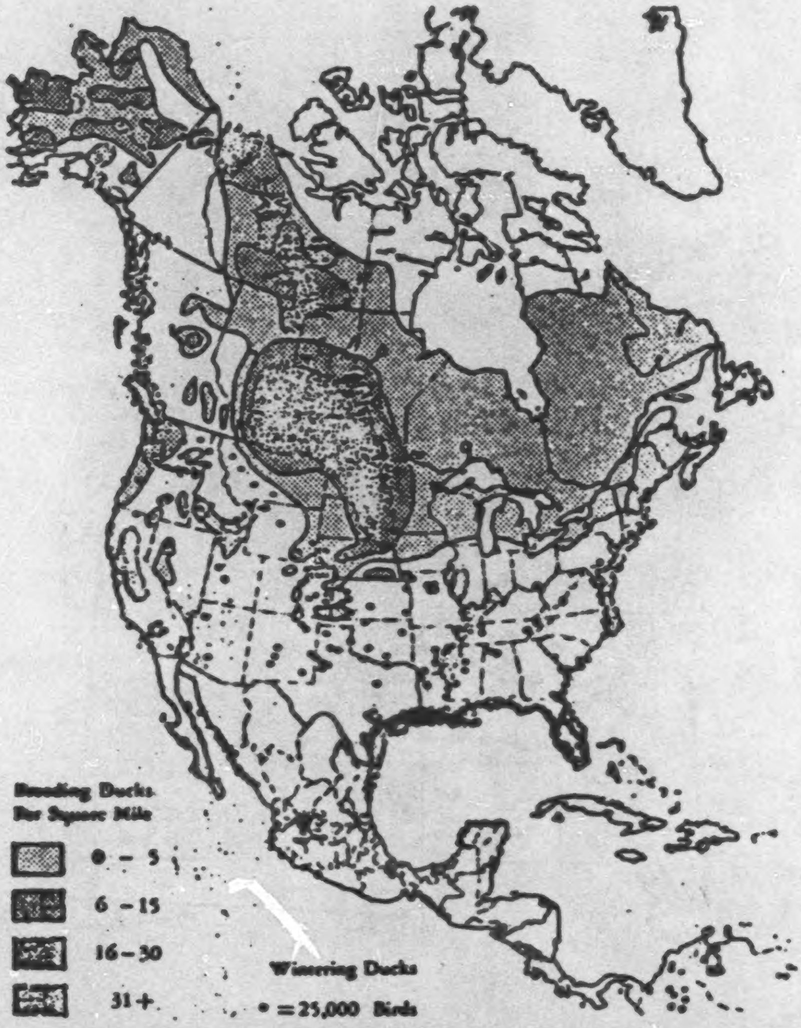


* EACH DOT REPRESENTS 10,000 ACRES.

Source: Poehlman, Breeding Field Crops, 1959, Henry Holt, New York.

FIGURE 6.

WATERFOWL PRODUCTION AREAS, UNITED STATES AND CANADA



Source: Evans, T.R. Beyond national boundaries, p. 717-722, In, Linduska, J.P. (ed.), Waterfowl Tomorrow. U.S. Department of Interior, Fish and Wildlife Service, 770 p., 1964

FIGURE 7.

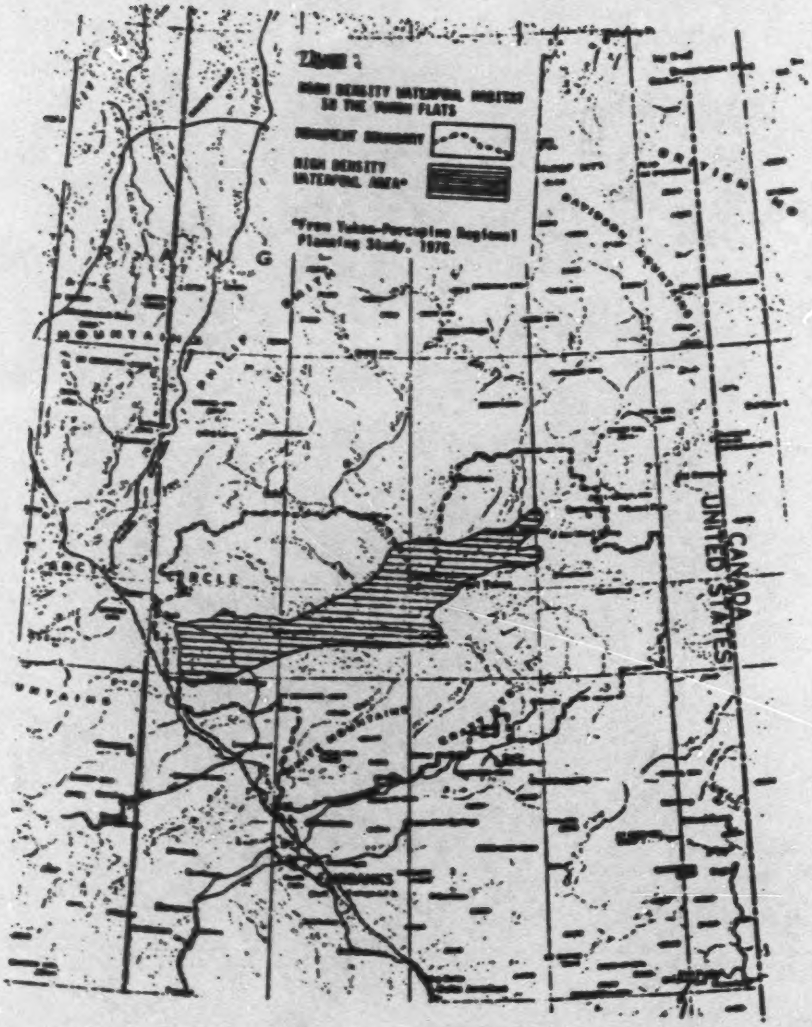

HIGH DENSITY WATERFOWL HABITAT IN THE YUKON FLATS
BOUNDARY
HIGH DENSITY WATERFOWL AREA*
*From Yukon-Porcupine Regional Planning Study, 1976.
MOUNTAINS
CIRCLE
UNITED STATES
CANADA

FIGURE 8.

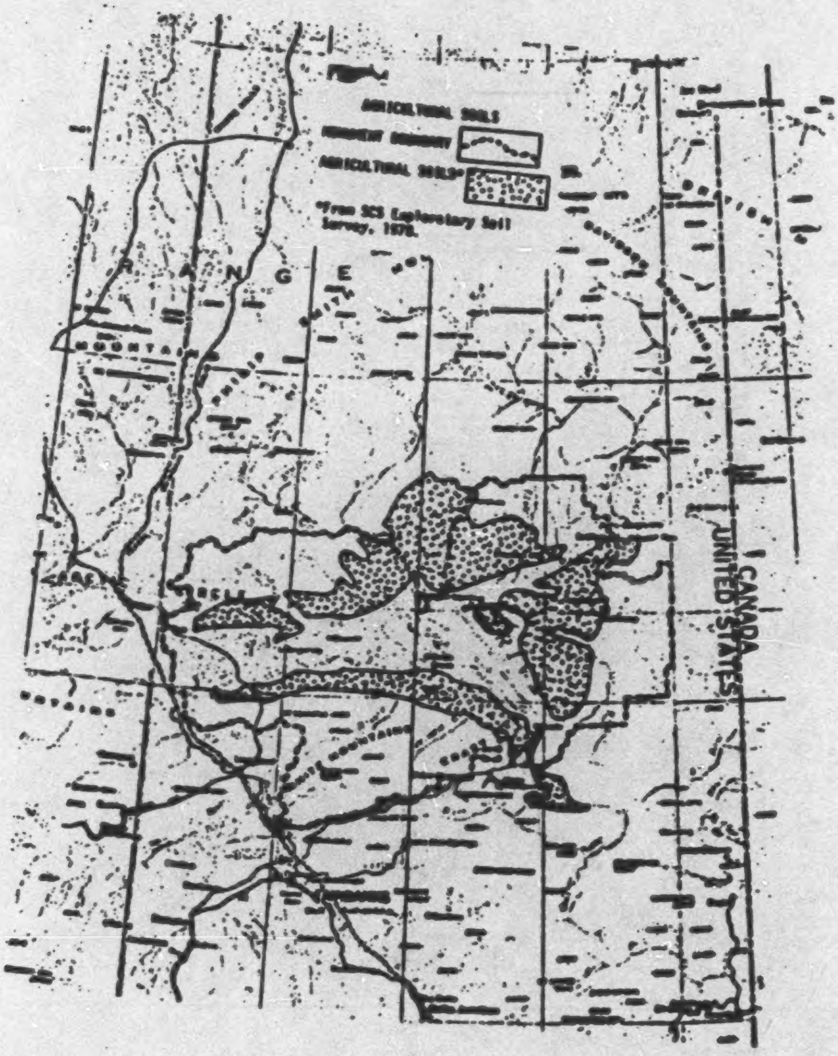
AGRICULTURAL SOILS
[illegible] BOUNDARY
AGRICULTURAL SOILS*
*From SCS Exploratory Soil Survey, 1978.
R A N G E
MOUNTAIN
CANADA
UNITED STATES

FIGURE 9.

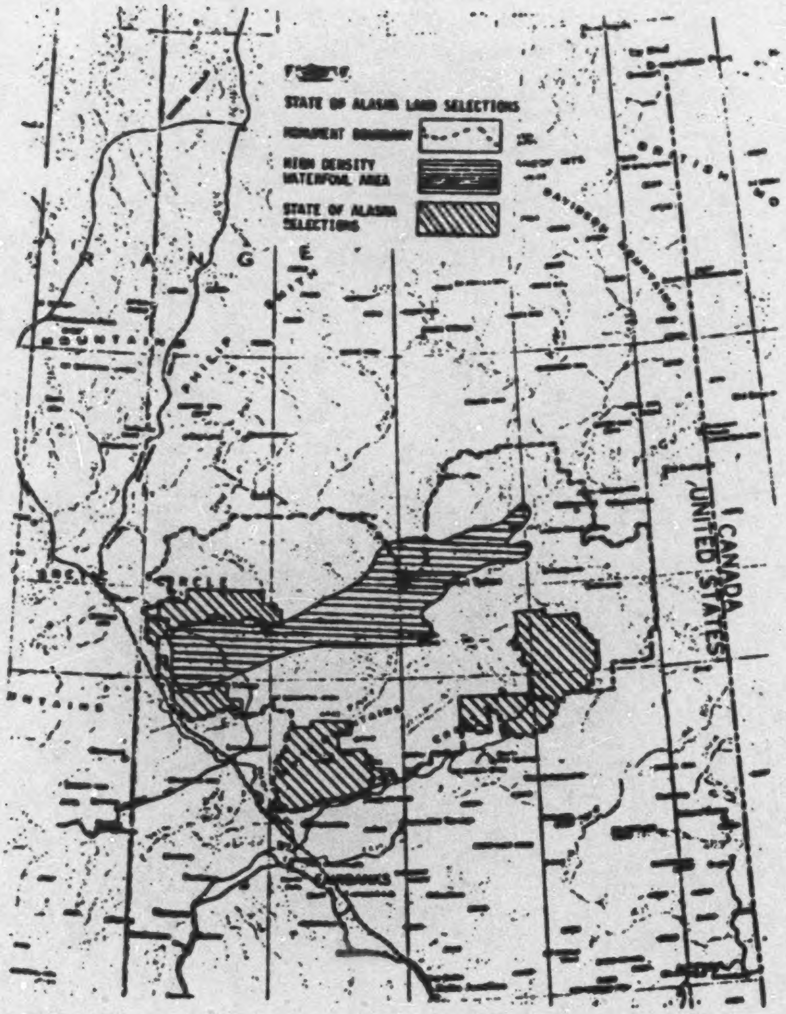
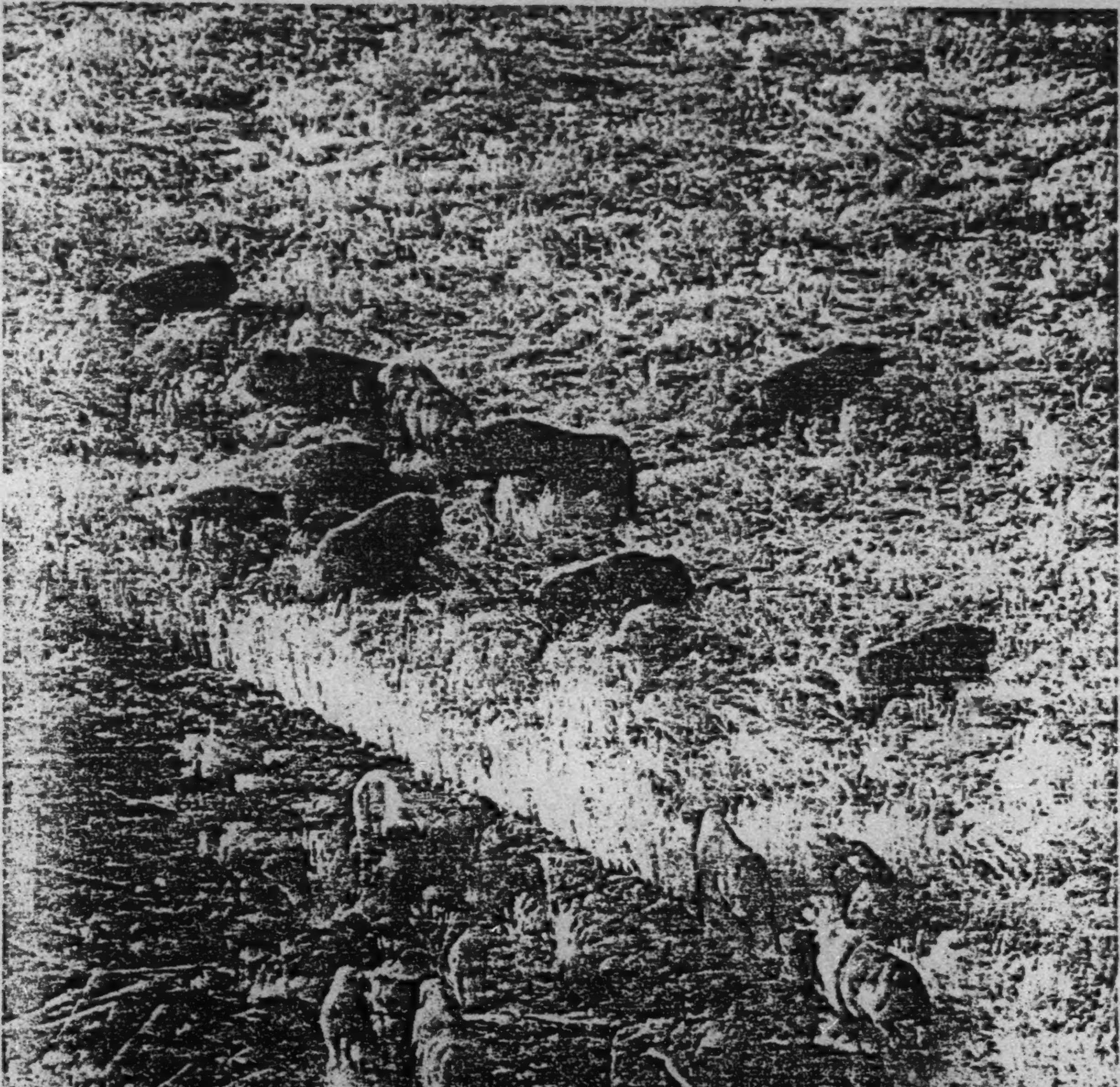

STATE OF ALASKA LAND SELECTIONS
MONUMENT BOUNDARY
HIGH DENSITY WATERFOWL AREA
STATE OF ALASKA SELECTIONS
R A N G E
MOUNTAINS
CIRCLE
FAIRBANKS
CANADA
UNITED STATES

FIGURE 10.

Figure 11.



BARLEY RAIDS—Bison are again raiding Delta barley fields, and damage to some individual farmers' crops is reported heavy this year. Bison problems surface each fall when the migrating animals move from the summer calving grounds and forage for fall food. The Department of Fish and Game and military officials hope to divert them from farmers' fields to remain on the 70,000-acre Delta bison range south of the state-backed agricultural project. *(Staff photo by Evan Bracken)*

2—Daily News-Miner, Fairbanks, Alaska, Monday, Sept. 15, 1980

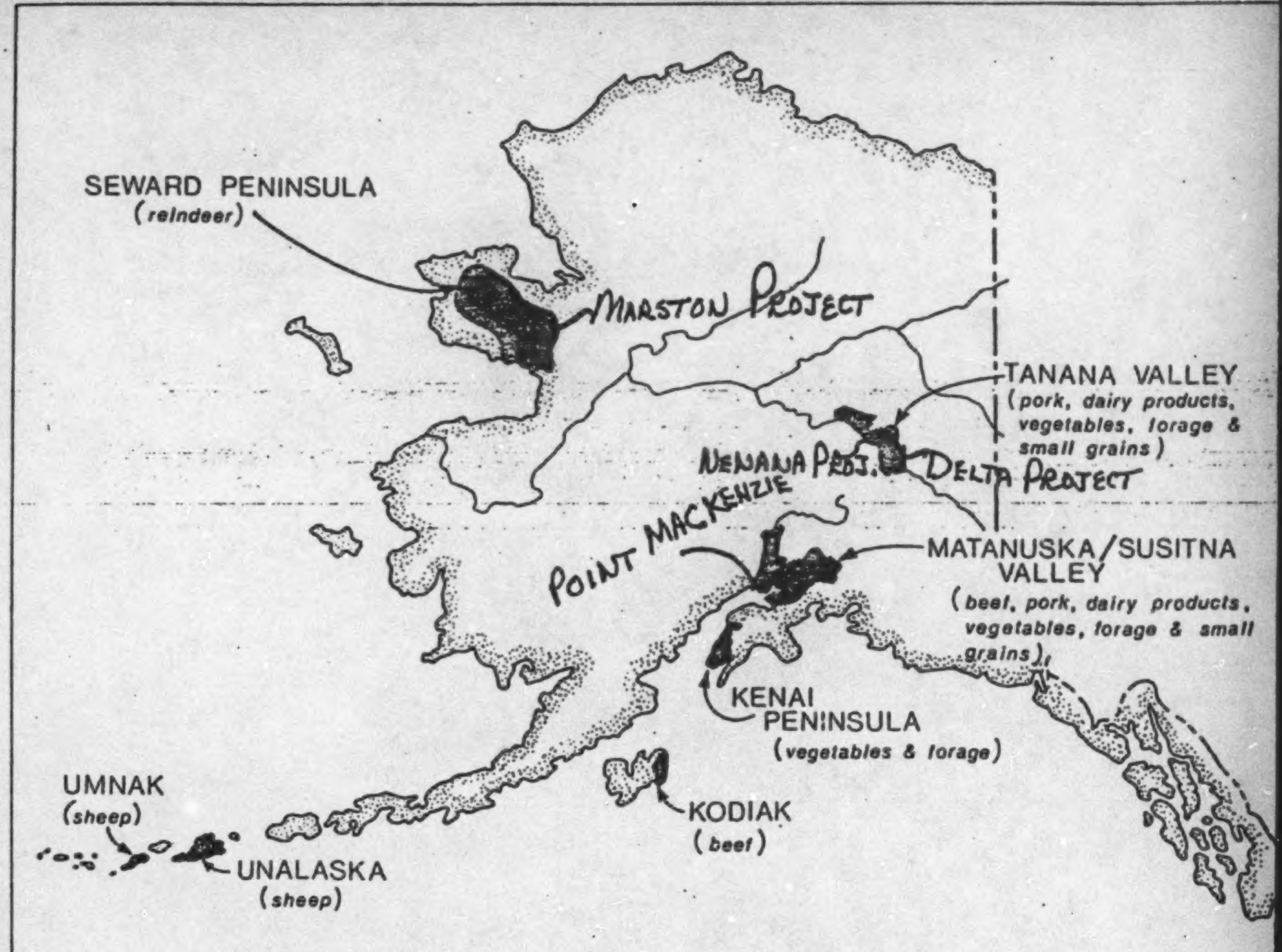


Figure 12: Main Agricultural Production Areas in Alaska.

*Wayne C. Thomas, "Agriculture in Alaska: 1976-2000 A.D," Alaska Review of Business and Economic Conditions, June, 1976, vol. XII, No. 2, Institute of Social and Economic Research, University of Alaska.

Figure 13. Comparison of Farm Cash Receipts and Dollar Value per Acre, Alaska & U.S., 1978, 1979

	ALASKA (1979) 1/	U.S. (1978) 2/
Acres in Production:	20,432	1,005,100,000 3/
Total Farm Cash Receipts	$6,689,000.	$111,042,089.000.
Dollar Value per Acre	$327.96/acre	$110.48/acre

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Background Paper No. 10

IMPACT OF COMMUNICATIONS TECHNOLOGY ON PRODUCTIVITY OF LAND

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October 1980

Office of Technology Assessment
U.S. Congress

This background paper was prepared for the assessment "Impacts of Technology on U.S. Cropland and Rangeland Productivity." The views expressed are those of the author(s) and not necessarily those of OTA.

ABSTRACT

This analysis concentrates on new, emerging and underused communications technologies by which information flows to agricultural producers in support of the long-range productivity of land. It explores the value of information in agriculture, sketches the major channels for agricultural information in the U.S. and summarizes some current forces which operate for change in agricultural information systems. Nine categories of information technologies are examined, with special emphasis on their potential uses in production agriculture: computer applications, cable transmission, satellite transmission, audio broadcast, telephone-related systems, other audio technologies, video broadcast, other video technologies and print media. The author also examines these developments in terms of public policy issues and concerns.

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Background Paper No. 10

IMPACT OF COMMUNICATIONS TECHNOLOGY ON PRODUCTIVITY OF LAND

A. Scope of analysis.

This analysis concentrates on one sector of the complex set of communications systems that serve the food-producing enterprise in the United States. It emphasizes the communications systems most directly related to maintaining, restoring and improving land for agricultural purposes. Therefore, it deals with ways in which producers gain information to optimize their production practices, such as tilling, fertilizing, controlling pests and harvesting; breeding, feeding, housing and caring for livestock; choosing and using inputs; and so on. It concentrates on the flow of information to producers from public and nonpublic sources of knowledge and stops at the end of the production stage.

Conversely, the analysis that follows does not emphasize a wide array of other communications activities related to agriculture. For example, it does not involve information about commodity markets or marketing, processing, promotion, nutrition or consumption. It does not include communications in rural community development. Nor does it include interactions between rural and urban parts of society concerning agriculture-related public issues.

New and emerging communications technologies are the focus of attention here. The analysis does not deal with the most basic communications medium in agriculture - word of mouth - which should, and will, continue to serve as the producer's primary way to gain, share and evaluate information on which to base farming decisions.

B. The value of information in agriculture.

Agriculturists have always understood that knowledge has value, that some state of knowledge undergirds every action a producer takes, that full and sound information leads to better outcomes than poor and limited information. Indeed, as Philip Abelson has observed, "Without communication there would be no science." 1/

In precise terms, however, the value of information is less well known. Only recently have researchers in agricultural social sciences concentrated on developing economic theories of information.

Agricultural extension has been one field of inquiry; economists have attempted to measure returns to public investments in agricultural extension. In 1975, the U.S. public invested (1967 dollars) about $63 per farm for production-oriented extension activities. 2/ What results do these information services produce?

Many studies indicate that agricultural research and extension in the U.S. produce 24 to 31 percent rates of return. 3/ And as far as extension alone is concerned, findings by Araji and colleagues suggest that 25 to 60 percent of the expected returns to public investment in agricultural research will not be realized without extension involvement. 4/

Another study measured the costs and social benefits of gathering and reporting statistics about farm commodities. Results led the researchers to conclude that the benefit from the investment in increasing accuracy for agricultural production statistics exceeds its cost by a wide margin. 5/

Research also emphasizes how important information is at the level of individual farmers and ranchers. Using a gaming approach, Debertin and associates compared the effects of research information on profits generated by experienced farmers in managing a simulated farm. Over the five-year gaming period, farmers who received research information generated annual profits that averaged 12 percent greater than those who did not receive research information. 6/

Especially within the past decade, agriculturists have become increasingly aware of the importance of information for producers. James Bonnen notes that "the further an economy departs from the assumptions of the Neoclassical model (where information is a free good), and the greater the level of uncertainty (up to a limit), the higher will be the value of information." 7/ As the United States food and fiber enterprise was released from the protective custody of farm program controls into an internationally interdependent market, producers moved into a sea of uncertainty, Bonnen explains. So the value of information jumped rapidly during the 1970s.

It continues to rise as producers face higher risks connected with higher prices of inputs (seeds, fertilizers, equipment and other), higher land values (with associated taxes and interest rates), greater losses of soil under intensive cropping practices, and other developments.

C. Major channels for agricultural information today.

Over the past 150 years, in particular, the U.S. agricultural enterprise has developed a complex, dynamic set of systems for moving production information to and from farmers and ranchers. These systems operate at many levels within agriculture, often with specialized purposes. 8/

Today some of the major agricultural information channels in the public sector include: agriculture study programs in secondary schools, colleges and universities; the extension system with activities at local, state and federal levels; agencies other than extension within the U.S. Department of Agriculture; state departments of agriculture; and other state and federal bodies.

Apart from the farmer's own experience, family members, friends and neighbors often are the most important non-public channels for information about production agriculture. Other major channels in the non-public sector include: the telephone (found in about 93 percent of U.S. rural farm homes) 9/; commercial farm periodicals (about seven of which are received in the average U.S. farm home) 10/; various breed organizations, commodity groups and other agricultural organizations (which have shown sharp increases in communications activity) 11/; marketers of agricultural supplies and services; radio and television stations; and newspapers.

Some of these operate as sources of farm information, as well as channels.

D. Pressures for change

New communications technologies certainly exert pressure for change in the flow of information to farmers and ranchers. Most of the following analysis focuses on those technologies and their possible effects.

However, the reader also should keep in mind some other developments that interact with technologies to exert impact on the productivity of land.

1. More information to move.

We are in a period of staggering increases in the volume of scientific information. On a worldwide basis, the stock of scientific texts was recently estimated to total 1,000,000,000 pages. 12/ Numbers of scientific journals have steadily increased tenfold every 50 years since the early 18th century. 13/

"The research and development process is clogged with printer paper," argues one analyst. "There is simply too much relevant material to be read in the limited time available for reading." 14/ For example, he estimates that it would take more than 27 centuries to read the annual biomedical literature, more than 7 centuries to read a year's chemical literature.

Agricultural information is showing the same kinds of growth, with the rate of increase of new agricultural literature reaching some 10 percent annually. 15/ The AGRICOLA date base provides an example. AGRICOLA, agricultural on-line system of the National Agricultural Library, gained 150,000 citations during 1977. It had added another 150,000 citations during the first eight months of 1978.

Increases in agricultural information arise not only from new research but also from new kinds of data that private and public agencies are collecting for use in food production. Some on-farm examples include infrared photography, monitoring of irrigation water, leaf analysis, detailed records on individual dairy or beef animals and other types of specialized data that were not feasible before data-processing equipment became more sophisticated.

2. Information becoming more specialized.

In general, agricultural development of a nation leads to specialization of function and structure, which in turn increases the demand for information. Such a trend is apparent in U.S. agriculture.

Of course, agricultural information has always, by its nature, been specialized. However, the degree of specialization of farm enterprises in the U.S. has increased rapidly since 1950. Both the volume and kinds of information required in production agriculture reflect this change. Even new branches of agricultural science have emerged: food technology, rural planning, landscaping, environmental management and others.

3. Information changing rapidly.

Results of chemical research may apply throughout the world, but results of agricultural research often are local. Findings often depend on environmental factors such as soil type and climate. Therefore, research to increase the productivity of land must be conducted in large numbers of settings, and even continued from year to year because local conditions vary over time.

The result is a rapid change in the content of information conveyed to farmers and ranchers. Under such conditions, agricultural information systems must renew and revise themselves continuously or lose their ability to offer timely, useful information.

4. Fewer producers.

Apart from pressures that arise from changes in amounts and kinds of content, agricultural information systems also are being affected by continued declines in the numbers of farmers and ranchers.

From a peak of 13.6 million in 1916, total farm employment in the United States dropped to 3.9 million in 1978. 16/ The number of farms dropped from a peak of 6.8 million in 1935 to about 2.3 million in 1979. 17/

These changes have had major impact, for example, on radio and television programming to farmers, and on the use of direct mailings and other individualized channels.

5. More education among producers.

In 1940 only 12.4 percent of rural-farm adults in the U.S. had completed four years of high school or more. Actually, 20.6 percent had completed fewer than five years of school. 18/

By 1977 the average rural-farm head of household in the U.S. had completed four years of high school (national median level of 12 years of school completed). 19/

This rapid increase not only boosts the appetites of farmers and ranchers for information but also makes them more able to gather the information they need and use it to their best advantage.

6. Rising costs and squeezed budgets.

Major increases in postal rates, pay scales, paper costs and other publishing expenses have added pressure to print media. Similarly, operating expenses for broadcast media, schools, and other channels of agricultural information have jumped rapidly during recent years.

Yet budgets in the public sector, particularly, have not kept pace with rising costs. Educational institutions such as the agricultural extension service have felt special pressure because of a long-term public policy of providing information services to agricultural producers, without charge. Such institutions are caught between the clients' needs for more information and the program manager's needs to cope with operating costs that outpace budget gains.

E. Some broad effects of these pressures

One can see several changes arising from the trends just described. Some of these are shared to one degree or another by parts of society outside of agriculture, but the emphasis here will be upon trends most apt to influence the productivity of land.

First is a general movement among farmers and ranchers toward continuing education, or life-long learning. Today's producers are more open to information than were earlier generations on the land. Indeed, as noted, they actively need more information to help them cope with greater risk in their enterprises.

Media segmentation is another resulting trend within agricultural information systems and one can see it in many forms. One example involves the emergence of controlled-circulation publications sent without charge to farmers and ranchers. Controlled-circulation publications became more prevalent as a means by which marketers of specific farm inputs could reach the increasingly specialized producer. Use of direct mail has increased as numbers of producers have declined. Even radio, noted as a mass medium, has moved toward "narrowcasting" concepts that involve highly specialized programming for certain farm producers.

A movement toward user-pay arrangements also is becoming more visible. To illustrate, until 1950 the subscribers to U.S. commerical farm periodicals paid less for their subscriptions than subscribers had paid in the 1800's. However, subscription rates nearly doubled between 1950 and 1970 and continued their rise during the 1970's. 20/ Many agricultural newsletters have emerged within the past decade, financed entirely from subscriptions. Within recent years the agricultural extension services in various states have begun to charge for some educational materials formerly offered free, even for some educational conferences and workshops that serve specialized farmer-clients. Expansion of cable television into rural areas offers another example of an increase in user-pay approaches.

Demand for timely (even instant) information is another trend growing from the pressures mentioned earlier. As producers face greater financial risks in their decisions --and as the body of production-boosting information grows in size, specialization and changeability -- timely information becomes more and more important.

The mushrooming volume of agricultural information offers clues to still another important change: toward information on demand. Under today's conditions, a farmer or rancher lacks the time needed to sort through large quantities of information in search of the specific answers s/he needs at a given time. A producer cannot afford to wait until those answers happen to appear in a newspaper or magazine article, farm radio or television program, series of extension meetings or other channels. The concept of information on demand begins with the individual producer's problems rather than with the judgment of professional farm educators/communicators. It already is becoming more visible in producers' growing use of consultants, call-in answering services and some other technologies that will be discussed later.

F. New information technologies and their potentials in agriculture.

As dynamic as the information technology scene is today, any effort to capture its fullness and diversity in a brief summary probably is presumptuous. Even the task of categorizing these technologies for discussion is difficult, for reasons that quickly become clear.

We are seeing a tremendous merging and blurring of traditional boundary lines among various kinds of information channels. Print media are becoming electronic, and vice-versa; personal media are becoming mass-ified (as in personal computer-created letters sent to millions); and mass media are becoming personalized (as in interactive, two-way television).

Our very concepts of time and space are being changed, primarily by the merging of computer and communications technologies into a common stream that has been called compunications technologies. 21/

Nine categories of technology will be discussed here, chosen according to general methods by which information is stored, processed, retrieved, transmitted and used. The emphasis is upon new and emerging information technologies, in particular those that are showing -- or may show -- important applications in the production of food and fiber.

The procedure will be to describe each method in terms of its operation, state of development, strengths, limitations and applications in production agriculture.

1. Computer applications.

This technology already is affecting farms and ranches in many ways, at many levels, although few producers have their own computers yet. It prompted one observer to note recently that computers are agriculture's newest input. 22/

Of course, suppliers of farming inputs are using computers in financial, production, marketing and other operations.

What is available to the individual producer?

Even without owning a computer, the producer now has access to some computer-based information services.

a. Farm management decision aids.

As an information aid for producers, the computer is now being used most extensively in helping solve farm management problems. A 1973 catalog of computer programs used in agricultural extension listed 425 programs from 37 states. 23/ An estimated 67,848 runs of these programs had been made in one year. These programs permit farmers and ranchers to make a wide variety of decisions geared to their individual conditions. Sample topics include selection of optimum feeding rations, cropping practices, fertilizer application rates, equipment purchases and many others.

Extension services in several states have developed these agricultural programs into information retrieval and analysis systems, available to producers in other states. Notable examples are Michigan State University's Today's Electronic Planning (TELPLAN), University of Nebraska's Agricultural Computer Network (AGNET) and Virginia Tech's Computerized Management Network (CMN). According to a report in 1978, TELPLAN was being used in 18 states, AGNET in 5 and CMN in 34. 24/

Similarly, some commercial firms have developed computer-based management aids for farmers and ranchers. In conjunction with a university, International Harvester Company developed the "Pro-Ag" computer system to serve producers who buy its products. The company placed terminals in or near its regional offices throughout the nation and sponsors seminars for producers to acquaint them with the terminal, the program and the decision-making service available. Producers feed data into the system, from their own operations, and use the computer to analyze the likely results of various management strategies.

Computerized management decision aids have the important advantage of tailoring information to the producer's individual situation. Such aids offer calculations that would be extremely time-consuming to carry out without a computer, yet they leave the decisions to the individual producer. Their effectiveness depends, however, upon the quality of data that the producer feeds into them and upon the soundness of the programming model. In some cases, management programs are being used where they do not apply.

A producer need not own a computer to gain access to such aids. In most instances today, the producer uses equipment and expertise provided by extension units or private organizations which sponsor the various services. Commonly-used remote access systems include: (a) printing terminal systems connected to the computer by long-distance telephone; (b) touch-tone terminal systems connected to the computer by long-distance telephone; and (c) mail-in systems whereby the completed input form is mailed to the computer site for processing and return. One study of these approaches showed that total costs (terminal and variable costs) averaged $32 per problem with the printing terminal system, $16 per problem with the touch-tone terminal system and $5 per problem with the mail-in system. However, mail-in was less acceptable to users; they preferred instant turnaround and interaction. 25/

Direct user access will probably become more common as producers gain access equipment and skill in using these computerized management aids.

b. Computer-based information services.

Whereas the management aid programs can help producers make decisions to increase their productivity, probably the computer's greater long-range impact will involve its capacity to store large amounts of information and retrieve it quickly. Potentials become clear as one thinks, on the one hand, about the individual farmer or rancher who confronts specific problems on a day-to-day, moment-to-moment basis and, on the other hand, about the possible answers to those problems -- stored in millions of articles, periodicals, books and other forms.

As one systems analyst recently noted, "Every Extension Service has thousands of bulletins, pamphlets, and other written information... that could be cataloged, stored, and retrieved quickly and accurately using computer technology." 26/

Today this kind of on-demand service is not generally available because producers lack ready access systems and (more importantly) because the information is not in forms suitable for computer access.

A huge task faces agriculture, in converting its store of printed information into such forms, and in creating systems by which new knowledge feeds smoothly into such forms.

Quite logically, information specialists have begun with the simpler (but still huge) task of creating automated bibliographic systems. The following illustrate some bibliographic data bases that pertain to food and food production. 27/

Abstracts on Tropical Agriculture. Produced by the Royal Tropical Institute, The Netherlands. Averages about 8,000 additional source items a year.

Agricultural Research Projects in the European Community (AGREP). Covers on-going agricultural research projects collected by the input centers of the European community. As of 1976, it contained 12,000 source items.

Agricultural On-Line Access (AGRICOLA). Maintained by the National Agricultural Library, Beltsville, Maryland. Exceeds one million records (90 percent of which are journal articles) and adds more than 150,000 records each year. The Bibliography of Agriculture indexing service is generated from AGRICOLA.

International Information System for the Agricultural Sciences and Technology (AGRIS). Established under the authority of the Food and Agriculture Organization. Approximately 70 countries contribute to the current awareness service of this system. AGRINDEX is the primary printed output from the AGRIS data base.

Commonwealth Agricultural Bureaux (CAB). The most comprehensive information service in the world for research scientists concerned with agriculture. Formed by the merging of 20 data bases produced by various bureaux to cover different aspects of agriculture. Abstract journals form a major part of CAB services to users. Data are available for on-line searching through the Lockheed Information Systems.

Current Research Information System (CRIS). Covers current projects in the research program of the U.S. Department of Agriculture, state agricultural experiment stations and other cooperating institutions. Contains research project descriptions. In 1977 the base contained about 24,000 source items.

These data bases by no means exhaust the list of automated bibliographic systems available within agriculture today. And the list omits completely what are known as factual data bases, which contain numberical and alphanumerical data as opposed to bibliographic references and abstracts.

Such data bases help agricultural researchers carry out literature searches and, thereby, help guide the direction of research projects.

Note, however, that existing agricultural data bases tend to be used mainly by scientists rather than by producers. Even the few systems, such as CAB, which provide abstracts are far removed from the concept mentioned earlier: specific answers to the producer's specific questions.

For visions of that concept we might look, to advantage, at what is happening commercially in the development of computerized information services for members of the general public. One such service is being offered by Telecomputing Corporation of America. This service, called "The Source," provides "low-cost computer time-sharing and access to many specialized data bases and programs oriented toward the home user. When the system is fully operational, its user will have access to data bases containing current news, business and financial information, consumer affairs, classified ads, dining-out guides for major cities, a directory of toll-free (800) phone numbers, etc. Special programs will include those for a variety of financial calculations (such as mortage costs), games, sending electronic mail to other users, and educational applications." 28/

If one forgets, for a moment, the equipment that a user might need in order to draw upon this type of information base, one can see what the future may hold for food producers who want timely answers to specific questions. Within this concept, sources of agricultural knowledge will put the information itself into data bases, not merely the citations or abstracts. Similar data bases, and possible systems for delivering information into the farm home, will be discussed in later sections.

To date perhaps the most ambitious experiment with computer-based information services to farmers is the Fast Agricultural Communications Terminal System (FACTS) in Indiana. 29/ The FACTS program, under way since 1976, now links 91 of the 92 county extension offices with other county offices, with regional offices and with a dozen campus terminals. What makes this system unique is the fact that all county and campus terminals are "intelligent," so have the capability to do more than transmit and receive information. Localized information can be fed into county computers while subject matter specialists at campus level also feed information that might apply statewide.

A producer may ask the county extension office for a certain kind of information. It may be available in the local data base, but if the problem is too much for the county terminal, the campus computer can step in to consider the problem. If that front-end processor cannot handle it, the problem is referred automatically to an even larger host computer which, if necessary, can call upon major data banks nationwide. Once the requested information is identified, it is transmitted back to the county terminal, usually within 10-20 minutes. Of course, the user gets faster answers to easier questions.

Some of the programming available on FACTS includes: field equipment calculator, double crop program, rations for beef cattle, installment land contracts, weather reports, real estate tax table generation, weather index calculator, crop pest management program, soybean seeding rate program, "blitecast" program to warn potato growers of potential late blight, break-even programs for feeder cattle and feeder pigs, and others.

The cost for equipment (computer, printer, etc.) in each county totals $18,000. Terminals are programmed to ask questions of the user and to give explicit directions, so no special language is required with FACTS.

c. Computer-based instruction.

The promise of computer-involved learning lies in its potential for direct, creative and responsive dialogue between teacher and student. The student can work at his or her own pace and get prompt feedback about progress. The student gains individualized instruction, a service not always available in the real world of limited education program budgets.

Early thinking about the development of computer-based instruction indicated that learners at individual terminals might be served by large, centralized computers. The PLATO system, developed since 1959 at the

University of Illinois, illustrates this concept. By 1980 about 1,200 terminals in 26 states and the District of Columbia were part of the PLATO IV system, each terminal providing its user with an interactive graphics capability with almost instant response to each input by the user. Terminals cost about $6,200 and users paid about $2,800 in user fees each year. Usage of the system totaled approximately one and one-half million contact hours of service per year by 1977. 30/

Recent advances in micro-processors and micro-computers have shifted the thinking of some who now envision a more decentralized type of computer-based instruction. This concept would argue that the future is more likely to find farmers and ranchers using micro-computers (their own or others at local schools, extension offices, businesses or other sites). Producers would use educational programs stored on floppy disks or cassettes, the two most common data storage devices used with microcomputers today.

Obviously, possibilities on the technical front are appearing rapidly. But on the software front, how many agriculture-related programs are available today in such forms? A review of the 1980 Hobby Computer Handbook Software Directory shows that among hundreds of programs available commercially, none deals with production agriculture. Even among the educational programs available, business management programs were perhaps closest to serving the professional needs of farmers and ranchers.

In short, it appears that general use by producers of computer-based instruction will await the emergence of software that serves their needs. As noted earlier, such educational material is likely to come first from the public sector (through extension services, for example).

Even within the public sector, experiences with programs such as FACTS suggest that the process of developing educational programming will be time-consuming and demanding.

d. The personal computer.

How visionary is speculation about computers in rural homes? Clearly, this innovation is in the very early part of the adoption scale. According to estimates by one personal computer marketing firm, 200,000 to 300,000 units will go into the marketplace this year, reaching only a small fraction of U.S. homes. Most buyers of such units are 25 to 50 years old, earn $30,000 or more a year and use computers in their jobs as managers or administrators. 31/ Some marketers are finding that the personal computer is being accepted by the general public more slowly than expected, often because consumers are uncomfortable with it.

Others, however, note the rapid growth of personal computers in the U.S. They point out that the total number of personal computers rose from fewer than 100 before 1975 to approximately 50,000 in early 1978. 32/ They foresee that during the 1980's personal computers will become as much a part of everyone's life as the television set, the telephone, the printed paper and the notebook. They envision everyone having access to his or her own computer. 33/ They estimate that the computers and ancillary equipment which sell for $3,000 today will cost only about $300 by 1988 -- and provide even more features and performance.

Specific uses of on-farm computers have yet to be explored fully, but many are apparent (even without the enhanced capabilities that interactive or two-way cable linkages would offer).

For example:

- -- Quick, easy retrieval of production information, either from the producer's own data base or from other bases.
- -- Use of farm management decisionmaking programs.
- -- Continuing education about production practices.
- -- Prompt access to marketing information as a basis for making marketing and production decisions.
- -- Communications with fellow producers, perhaps through specialized personal computer networks.
- -- Financial management of family and farm/ranch affairs.
- -- Recreation.
- -- Real-time control of home and farm appliances.

Limitations at present seem to center mainly on points mentioned earlier:

- -- Training that users will need if they wish to take full advantage of their computers.
- -- Costs of the equipment, programs and access linkages.
- -- Scarcity of computer programs and data bases that can serve the special needs of agricultural producers. It seems safe to say that, today, the information delivery mechanisms are better than the information available to deliver to producers.

These are serious limitations and in the short run it seems likely that agricultural producers will rely mostly on computer-based information services available to them from various public and commercial sources. In the longer run, the personal computer holds real promise as a means of increasing the ease and efficiency of farming and ranching.

2. Cable transmission

Uses of coaxial cable to transmit television signals have been developing for more than 30 years, causing some experts to consider cable television the most significant of the new mass communications technologies. It began slowly and in 1960 served only about 650,000 subscribers in 640 systems. 34/ But when the domestic satellite became available in the mid-1970's to feed programming into cable systems, the cable television industry experienced a "frenzied renaissance." Cable penetration reached 21 percent of the national audience in 1979 and by early 1980 more than 15.4 million homes were wired to cable systems. New subscribers were being added at the rate of 8,000 a day. 35/ Forecasts for 1985 range from 20 to 40 million homes. 36/

What may this combination of satellite and cable technologies mean to agricultural productivity?

Several early programming experiments may offer clues about the potential for cable communications in rural areas.

At the simpler levels, specialized program services for farmers and ranchers could be offered by allocating all or part of a video channel to such programming. The Reuters Monitor Service in lower Manhattan illustrates this use. Subscribers can buy various kinds of market information: grain, livestock or other. 37/

Greater potentials for cable reside in wide-band two-way technologies which permit interactive information services. The QUBE System introduced in Columbus, Ohio, during 1977 offers a commerical example. If a program host on one of the QUBE channels wants to learn how viewers feel about something being shown or discussed, s/he simply displays a question on the home screen. Viewers then use a control box to register their opinions (yes, no, undecided) and within a few seconds the results of the system-wide survey appear on the screen.

More sophisticated interactive systems have been widely discussed and, to some extent, tested. Examples of field experiments include a system in Trempealeau County, Wisconsin, applying the principle of cooperative-type financing of two-way cable in a sparcely-populated rural area; a system in Spartanburg, South Carolina, designed to experiment with the use of two-way cable in adult education, training of day care workers and communications between social service agencies; and an interactive system known as TICCIT that operated in Reston, Virginia. 38/

Still more sophisticated is a system known as Highly Interactive Optical Visual Information System (Hi-OVIS) recently set up in a pilot town (Higashi Ikoma) in Japan. Hi-OVIS provides full two-way communications capabilities using optical fiber cable. It links the home (which has its own camera, microphone, keyboard and terminal controller) with an array of subcenter and center facilities, plus mobile center facilities which collect and transmit information from local schools, police departments, city offices, fire departments, hospitals, stores, transportation facilities, the press and other sites. Social experiments on Hi-OVIS have been conducted since mid-1978. 39/

Clearly, the uses envisioned for interactive cable systems are impressive. For example, an Office of Technology Assessment study of uses of broadband communications in rural areas identified these potentials:

Public

Health service delivery to rural areas.

Rural education.

Law enforcement (roll calls and briefing sessions, transmitting fingerprints and related documents, officer training, monitoring of traffic and special events, other).

Other governmental/administrative uses

Commercial

Security systems for rural sites.

Information services for producers and their families.

Data transmission services (such as remote and automatic meter reading, internal communications, teleconferencing)

Pay television (entertainment, other).

Rural applications are apparent in other uses now being examined and tested: electronic funds transfer, energy management, medical alert, computer time-sharing, subscriber polling, electronic mail, electronic games, comparative shopping information, stereo music and radio.

However, not all cable systems that exist today have two-way capabilities. Cable system operators have yet to find the variety of new services which would justify the added cost of two-way transmission or switching capabilities. And costs are likely to remain prohibitively high for a considerable period. 40/

An even more basic limitation in rural areas is that cable television is generally not available now, nor likely to be available soon, because of high capital costs in laying lines. By one 1978 report, the rule of thumb in the industry is that a cable system needs at least 30 to 40 households per cable mile to generate a sufficient return on investment. 41/ Obviously, farm subscribers create an unpromising market for commercial cable, given the current rural population density, programming services available and cable technologies. Today's farmers and ranchers find themselves in a situation much like their forebears faced earlier in this century when telephone and electric services came first to the more populous areas and only later into rural areas.

Of related concern to producers is the possibility that cable systems, as they develop along pay-tv lines, may weaken the present "free" commercial radio and television stations on which producers depend for information.

3. Satellite transmission

Agricultural producers benefit from satellite systems which permit the monitoring of weather and crops, but the current analysis is directed, instead, toward communications satellites and their potentials for farmers and ranchers.

Many technological improvements have occurred since the first commercial satellite was launched in 1965: greater power, greater communications capacity and smaller receiving stations, for instance. Four North American communications satellite systems went into operation between 1973 and 1976. 42/ Originally, planners thought that satellites would distribute television programs to commercial networks, the public television system and independent stations. However, the commercial networks have not found cost advantages in moving to satellite transmission, so at present satellites are used more extensively to interconnect cable television systems.

If cable lines are expensive to lay in sparsely-populated rural areas, what are the potentials for getting information to producers by direct satellite broadcasting?

Certainly direct satellite broadcasting is technically feasible.

Also, it has proven value in delivering education and social services. Canada's communications technology satellite, Hermes, has become the main vehicle used by various Canadian public service agencies to assess how well satellite communications might serve their needs. Hermes was launched early in 1976 and used in six education experiments, a telehealth care experiment, teleconferencing and data transmission experiments, an interaction experiment involving citizens in two communities and three broadcasting experiments. Researchers found the Hermes system reliable, flexible and effective in supporting the work of public service agencies in remote and dispersed areas. 43/

A Satellite Television Demonstration Project in Alaska also has demonstrated some educational potentials of direct satellite broadcasting. It tested the feasibility of using small earth stations for education in rural-area schools and communities. The first instructional television programming began early in 1977 with 10 hours of broadcast instruction a week. Later, all of the teachers, parents and students involved in it said they wanted the programs to continue. Especially well accepted was an adult educational series, GED by TV. 44/

However, the limitations of direct satellite broadcasting make it less promising in the short run than some other technologies available to U.S. farmers and ranchers.

Cost is one limitation. A three-meter dish suited for home reception of television signals for private use cost about $6,000 to $7,000 in early 1980. 45/ Walter Baer reports a recent study for the National Research Council which showed that a 1.3-meter antenna capable of receiving 12 color television channels transmitted at 12 GHz could be installed for about $250 if mass produced in the millions. Baer continued: "Even at $250, a satellite receiver would be far more expensive than an ordinary broadcast antenna and considerably more than the average cost per household to build a 12-channel cable television system. Moreover, it is not clear what advantages direct satellite broadcasting could have for U.S. households in metropolitan areas. Rural Alaska could certainly utilize satellite broadcasting, but in other U.S. rural areas, such a system would seem to be less cost-effective than extending over-the-air television service with translators." 46/

Apart from the cost limitations, those who have worked with direct satellite broadcasting systems for educational purposes point toward other limitations: resistance from teachers and others who work with learner-audiences at the receiving sites; cumbersome organizational structures; neglect and inadequacy of software; improper use of such systems, based on one-way rather than two-way, interactive communication models; and others. 47/ Regulatory and public policy questions also will be important to the future of this technology.

4. Audio Broadcast

U.S. farmers and ranchers have been served vigorously since the 1920's by commercial radio stations that provide farm programming, often through the services of full-time farm reporters. Producers have relied, and continue to rely, heavily upon farm radio for timely reports of news, weather and commodity market prices. Today relatively little farm radio programming offers "how-to" information about technical aspects of farming. That is because in recent years the on-farm population has dropped to such a small share of broadcast stations' total listening audience. The same audience trend has prompted some shifts in the kinds of radio stations that are most active in farm programming. Originally, clear-channel and other large stations carried the most farm programming. Many of those stations are in highly-populated markets, however, so in recent years farm radio programming has shifted somewhat toward smaller, rural stations.

On the technological side, some noteworthy developments include the following:

a. FM broadcasting.

The expansion of FM broadcasting in the U.S. has brought with it some increase in the amount of farm broadcasting on FM stations. However, farm programming is not prominent in most FM stations.

b. Farm radio networks.

At least 40 farm radio networks now serve rural interests in various parts of the nation. Most of these networks are independent, commercial program services marketed to stations under various arrangements. They range from live broadcasts to audio tape services. Some are offered on a year-around basis while others are offered to stations seasonally, geared to the growth cycles of specific crops. Examples include American Cotton Network and Great Plains Beef Network.

These networks help make farm programming available on stations that cannot afford to employ farm reporters; in that sense they may increase the farm programming carried by commercial radio stations, in aggregate. Their effects on stations and farm programs with which they compete for audiences and advertising support are not documented.

5. Telephone-related systems

The telephone has long been integrated into the living patterns of rural families. It is one of the producer's main communications links -- interactive, accessible, easy to use, flexible and relatively low-cost.

Now the telephone is being combined with other technologies to create new potentials for usefulness.

a. Combined with the computer and television set.

One of the most interesting possibilities involves linking the home television set with a computer data base, through one's telephone. The process is much like calling a local number for a weather forecast, except in this case the weather map and forecast appear on one's television screen.

This combination -- variously known by terms such as viewdata, videotex and wired teletext -- was pioneered in the United Kingdom by the British Post Office as a possible way to offer nationwide information services to the general public as well as to professional users.

A two-way interactive system, viewdata requires a special decoder (built into the home television set, or connected to it), and a telephone connection to the central data base through a coupler. When connected, an index page appears on the screen and the user presses numbered keys to order certain "frames" or "pages" of information. Viewdata has a potentially unlimited information base from which the user can draw. Even for the initial field trial the British Post Office system offered over 100,000 frames of information provided by various organizations. Information that is requested appears on the user's screen within 11 seconds. 48/ Then, because viewdata involves a direct connection, the user can be billed for information received.

The British Post Office system, known as Prestel, underwent field trials beginning in 1978 and already has counterpart systems in various stages of development in at least 15 countries.

Viewdata is being tested on several fronts in the United States. In a sense, "The Source," a computer-based information source mentioned earlier, is similar to viewdata. The difference is that "The Source" uses a computer terminal rather than a television set as a display device.

Among the other U.S. systems under trial is Viewtron, tested in Coral Gables, Florida, by Knight-Ridder Newspapers. Information in the system includes local, national and international news, weather, sports, calendars of local events, lists of adult education courses, product ratings, local movies, restaurant and theater hours and other material provided by companies, organizations and publishers.

One of the most interesting pilot uses involves information services for farmers. The system is called Green Thumb, sponsored jointly by the National Weather Service, U.S. Department of Agriculture and the Kentucky Cooperative Extension Service. 49/

The Green Thumb approach, designed by Grumman Data Systems, uses the farmer's home television set and requires installation of a relatively inexpensive (about $215) telephone/television interface device. The farmer uses the keyboard on the Green Thumb box to select frames of data for viewing on the screen. The keyboard also can be used to send information such as weather data back into the system. A central data base exists at the University of Kentucky and early in 1980 contained 1,000 frames of data for the farmers in the two experimental counties. Each county office has a microprocessor which permits on-site extension workers and others to enter localized information for text, charts or maps. The county contact also allows users to make local rather than long-distance calls to access information from Green Thumb.

Users can get weather and market price information (updated at 15-minute intervals), area news, local weather observations from user-farmers and timely information about pest management, agricultural economics, forestry, animal science, plant pathology and horticulture. Users receive a printed "menu" of information available, identified by numbers that users feed into the Green Thumb box when making a telephone call. From any given call a farmer can access up to 16 pages of information.

Equipment costs for this system include a $60,000 to $90,000 central computer, a $6,000 to $10,000 microprocessor at the county level and a Green Thumb box at the farm level. Private rather than party phone lines are required.

This same viewdata concept is entering the commercial market now, directed at first to institutional and commercial users. Tandy Corporation plans to market a new TRS-80 Videotex system which hooks up with a telephone and television set. The unit is priced initially at $399. 50/

Viewdata brings the computer into the farm home perhaps as simply and easily as any present technology. Theoretically, it can offer unlimited amounts and kinds of information through a simple telephone call. No special language is required of users. Its interactive capabilities also offer important advantages for viewdata. And equipment costs for the Green Thumb type of system are relatively modest.

However, no one knows yet the cost of such agricultural information services on a commercial scale. Producers' response to charges for specific pieces of information remains untested. By one estimate, a viewdata system serving a general population of 250,000 persons would cost about $12 a month (not counting the cost of user terminals or terminal rental charges). 51/

Furthermore, data bases for such agricultural purposes are yet to be formed on a broad scale. They will be complex and time-consuming to generate, especially as they move toward information tailored to local interests and conditions. At present it is not even clear whether such agricultural information services might take shape within the commercial or non-commercial sectors, or both. Existing counterpart services for the general public (such as "The Source") are commercial, but Green Thumb is being tested in a non-commercial setting. Within agriculture, the most likely sources of information for such data bases are the government agencies, colleges of agriculture (with their research and extension capabilities) and commercial information-gatherers such as farm publishers and commodity news services.

Prevalence of party telephone lines in rural areas also raises barriers to the use of viewdata systems.

b. Combined with the computer.

Many uses of the "intelligent telephone" are being examined and some have potentials for helping boost agricultural production.

An experimental service called "advance calling" illustrates this combination of telephone with computer. It is being tested in Philadelphia by American Telephone and Telegraph. An agricultural extension adviser could use it to warn local producers of pest infestations, approaching storms or other important matters in which speed is important. The adviser would call up the computer, record a message, then enter into his pushbutton phone the telephone numbers of those to receive the message. The computer, which can be programmed to dial a list of several hundred phone numbers, then takes over and delivers the recorded message to all of the phone numbers specified. If no one answers at a given number, the computer makes repeated attempts for several hours until the call is answered.

This system works well with short messages and is expected to cost 30¢ to 60¢ a call. One advantage is that it permits calling large numbers of persons simultaneously. The marketer estimates that this service may be available to about 30 percent of the nation's phones by 1985. 52/ It may be used more by those who communicate with producers than by producers themselves.

The "intelligent telephone" also holds promise for use in conference calls, call-forwarding, financial transactions, clock and calculator functions in the farm business office, remote control of appliances, commodity price quotations, voice libraries of recorded information and other activities. 53/

c. Traditional forms.

In an era of rapidly rising transportation costs, the familiar telephone emerges more clearly as a basic (even underused) information channel for enhancing the productivity of land. It is widely available, uses a low-cost terminal, permits interaction at the personal voice level, is price-competitive, is easy to use and puts users into contact with an increasing, worldwide network of information sources. The basic voice-phone system is likely to continue -- and strengthen -- its role as "backbone of the entire telecommunications system." 54/

How can the telephone system be used more fully and effectively in support of food and fiber production? Two examples of recent experimentation may illustrate.

One involves dedicated telephone networks such as the TeleNet system which the Illinois Cooperative Extension Service has been operating since 1970. TeleNet links county and regional extension offices throughout the state with each other and with researchers and subject matter specialists at the University of Illinois. At one level, it operates as a "party line" over which educators can confer with each other, individually or in groups, for administrative or programming purposes. At another level, it serves as a means of in-service education for extension personnel to stay up to date and increase their capability to help their clientele. At still another level it becomes a channel for teaching clientele directly, through educational meetings and workshops about a wide variety of topics. One advantage of TeleNet, as a channel for teaching, is that both students and teacher(s) can be at any site(s) on the network.

Whereas the telephone network is limited to audio communications, it can be supplemented by other instructional methods at local sites. Its interactive potentials give it many of the advantages of personal conversation. Research shows that audiences accept this form of distance teaching, and learn effectively from it.

British Open University is experimenting with the telephone as a way to help individual students. The University's operations cover the entire United Kingdom and rely heavily upon printed materials sent by mail to students' homes. Face-to-face contact between teachers and students is costly and difficult, so the University is testing several uses of the telephone: (1) one-to-one telephone tutoring; (2) telephone contact between a tutor and a group of students at a study center; and (3) telephone conferences involving several telephones. Early results show particularly high use of the telephone-tutoring options by remote students. 55/ As continuing-education activities of U.S. farmers and ranchers become more systematic during the years ahead, this use of the telephone may help provide personal instruction to accompany other means of learning.

6. Other audio technologies

The two types that follow by no means exhaust the possible audio technologies that could be discussed. However, they represent two technologies that may have special implications for production agriculture.

a. Audio cassette

Whereas the cassette system is less sophisticated than some other technologies discussed here, it may hold valuable potential in an era of increasingly specialized agricultural information. Audio cassette technology involves battery-powered or plug-in units that play back (and usually can record) information stored on magnetic tape installed in small, sealed cases.

Audio cassettes have been used more widely for continuing education among groups such as doctors than among farmers and ranchers. Future uses within agriculture may involve (a) updating extension persons and others who channel information to producers at local levels and (b) use by farmers themselves. The latter use is becoming increasingly likely as cassette recording and playback units become available to more rural families.

The low cost, simplicity and mobility of audio cassette technology help make it attractive for use in agriculture. 56/ A producer can listen to a tape while choring, driving a tractor or doing a variety of other tasks. Users, themselves, control the information they get, when they get it and how often they listen to it. Another advantage of the audio cassette is that content for it can easily and inexpensively be produced locally. An extension worker can make timely, local information available to farmers and ranchers at modest cost, and with the advantage of the local human voice. So audio cassettes can work especially well in educational systems (such as extension) that combine personal and mass methods of communicating.

Broken equipment, dead batteries and similar mechanical problems come with the audio cassette technology, as a limitation. Also, programming involves some cost. But the more important limitations of this technology arise from a current shortage of programming for producers; little is being produced at present, either at local or other levels. Distribution of such programming remains a barrier, too. Local outlets for music cassettes are well established, but such is not the case for informational cassettes directed to farmers and ranchers.

b. Mobile audio communications

Mobile communications have special use for farmers and ranchers because their work sites are diverse and scattered. Types of such services include:

Paging services - They provide one-way transmission from a base station to mobile paging units. Future improvements will allow pocket pagers to record or display a brief message, such as the name and telephone number that the paged party is to call.

Citizens band (CB) radio - These open-line broadcasting systems have gained widespread use among farmers and ranchers within the past decade. CB units help users ask for advice and aid, conduct business and carry out dozens of other activities.

CB, the most commonly-used of these services among producers, involved an estimated 35 to 40 million users in the U.S. by late 1976. 57/ It still has potential for greatly expanded usage in agriculture as users find new ways to apply it in their operations.

Over the longer range, mobile communications may take new forms, including linkages between satellites and mobile receivers (such as wrist-radios). This technology already has been demonstrated. A second attention-getting development is packet radio, which employs digital transmissions for both voice and data communications.

These and other mobile communications systems are likely to become more widely used among producers as low-cost ways to save time, travel and effort in their work. Such tools can pay for themselves quickly, especially in emergencies.

7. Video broadcast technologies

a. Broadcast teletext.

Wide interest being shown in this technology, internationally, arises from its potentials for home information services akin to those which wired teletext (viewdata) offers. Teletext is becoming a generic term used to describe the broadcast of text and graphics as part of the television signal. A user chooses "pages" of information which are being transmitted continuously in recurring cycles. To access information, the viewer consults a contents page, then punches in the desired pages on a keypad. A decoder associated with the television receiver grabs the selected pages and transfers them to the user's screen.

Broadcast teletext systems called Ceefax and Oracle have been operating in the United Kingdom since 1974. 58/ Similar systems have appeared in other European countries, including France with its Antiope system. Ceefax was developed initially by the BBC as a means of subtitling for the deaf. However, it has developed into a comprehensive source of information ranging from pie recipes to weather maps, road travel reports, concert listings, sports headlines and police news for children.

Teletext experiments are under way in the United States, but the practical applications of broadcast teletext have not gone as far as in the United Kingdom and elsewhere. Samples of U.S. experiments include those by Bonneville International Corporation, owners of KSL, Salt Lake City, Utah; KMOX-TV, St. Louis, Missouri; and Micro-TV in Philadelphia. 59/

Broadcast teletext offers many of the same advantages as wired teletext (viewdata). It links the home with computer data bases that can provide large amounts of information quickly. The information can be updated continuously, so few media can match it for immediacy. Users choose the exact information they want and the time when they want it. Then they control the amount of time they spend reading it; they can even refer back to earlier pages. Broadcast teletext can present graphs, maps and diagrams, but not conventional photographs. 60/

Limitations of broadcast teletext also are noteworthy. It is a one-way system, so cannot interact with the user as viewdata can. It can handle only a limited data base, whereas the potential base for viewdata is nearly unlimited. To illustrate, a small viewdata center might access from 70,000 pages of information within two seconds. A broadcast teletext system with 800 pages may require a waiting time of three minutes. Cost of the home decoder remains another limitation of teletext; by one estimate for 1979, the teletext-equipped television set would sell in the United Kingdom for about $300 more than a basic television set. Broadcast teletext also poses greater problems than viewdata in charging users for information.

Uses of broadcast teletext for agricultural information remain largely untested in the United States.

b. Standard television broadcasting (commercial and public).

Television programming for farm audiences has not developed as fully as has radio farm programming in the U.S. Only 68 commercial television stations were listed in the 1979 Marketing Services Guide as offering farm programming.

Farm and ranch viewers account for such a small share of total television audiences that most stations have not offered farm programming. Marketers of farm supplies and services invested nearly $45 million during 1979 in television advertising directed to producers. 61/ However, a majority of the commercials were placed in conjunction with general news and weather programs rather than farm programs.

So farmers and ranchers are getting some of their input-decision information through television, but relatively little information about production agriculture. This situation seems unlikely to change much in the general broadcast television sector.

c. Translator stations.

Testimony at 1977 U.S. Senate subcommittee hearings about rural telecommunications revealed major differences in views about the potentials of translators for serving rural areas. 62/ Testimony by the National Translator Association argued that television broadcast translator stations, with their relatively low initial capital and low maintenance costs, are ideally suited to serve sparcely populated areas. These low-power broadcasting stations receive incoming signals of a television or FM radio station, amplify the signals, convert them to a different output frequency and retransmit them to a given area. At that time, translators cost $1,500 and up; maintenance $50 or more a year.

According to an example cited, seven translator channels could serve a given local area. Five channels would re-broadcast television signals and two channels provide social and related services. These channels could either operate on a dialogue basis or operate independently with the return being by telephone. The transmitting channel would be aural and visual; the return would be aural. According to testimony, such a series of public service channels could be established for $5 to $20 a family where translator stations already operate, or less than $100 where no translators currently operate.

In summary, the Association estimated that translators could provide 90 percent of the service of a cable system for 10 percent of the cost.

Cable operators, on the other hand, emphasized the greater capabilities of broadband communications over translator signals and pointed toward other translator limitations such as electronic interference and unreliable equipment performance.

Because most rural areas lack cable services at present, and are not likely to get them soon, the service-channel potentials of translators for getting production information to farmers and ranchers may deserve careful testing.

d. Mini-TV.

A unique version of the translator technology has been applied in Alaska where special efforts have been made to bring television to rural areas. In 1973 the Federal Communications Commission granted a waiver of certain sections of the translator rules to permit the establishment of mini-TV stations in Alaska. These are 10-watt translators which can play programming by videocassette rather than by off-air pick-up. Forty-one mini-TV stations were operating throughout Alaska by 1977, 23 of them served by satellite television and 18 using cassette mini-TV. 63/ Both uses of the mini-TV technology invite examination for use in rural areas elsewhere in the U.S. One noteworthy finding of the Alaska program is that the mini-TV concept, teamed with videocassettes, gives local users greater control over programming than standard translator systems provide. Local communities produce some of their own programming and get other videocassette programming from fellow mini-TV stations and other sources.

8. Other video technologies

Videodisc and videocassette technologies are being applied in support of food and fiber production, mainly through schools, extension services and other organizations that conduct educational programs for producers. Relatively few U.S. homes (rural or otherwise) have such systems at present. Only about 1.2 million videocassette units have been sold in the U.S. while sales of the even-newer videodisc units will total only 10,000 to 15,000 during 1980. 64/

Both of these technologies offer users the potentials of color, sound, motion and referability. They also share the disadvantage of relatively high cost for equipment and programmed cassette or disc.

Videotape cassettes offer some distinct advantages over discs: they permit the user to record any program from the television screen and retain a copy for the user's files, whereas the videodisc is pressed at the factory. Also, with a camera added, one can produce one's own programming on videocassette.

However, the videocassette suffers from several disadvantages, compared with the videodisc: programming cannot be accessed randomly; equipment and programming cost more; the tape-handling features make cassette technology more trouble-prone; tape programming wears out faster than that on discs (which use a laser stylus); and tape systems cannot currently handle still-frame retrieval.

Videocassettes are being used successfully for agricultural instruction in schools, and in continuing education programs for farmers and ranchers. For example, the Cooperative Extension Service in Kansas teamed videocassettes with a statewide telephone network to teach a series of pork clinics during 1974. Producers watched a videotaped presentation at each of 11 local sites. Then all meeting sites were connected by telephone for "party line" discussion. Researchers found that more than 97 percent of the participants recommended the continued use of this combined teaching method. 65/ The Kansas researchers concluded, in another study, that cassettes are less successful when they are not followed by a question-answer period. 66/

For instructional purposes, videodisc may offer greater potential than videocassette - especially as the computer joins existing videodisc components (player, program disc and color television set).

Andrew Molnar explains that this "intelligent videodisc" system would "be capable of presenting color video, freeze frame action, forward and reverse slow motion, randomly accessed frames, two audio channels, and be capable of utilizing stored digital information from either the videodisc or the computer and would be capable of student interactive operation in a typical educational environment. The video-disc system would also be capable of presenting a half-hour television program or providing random access to 54,000 frames (enough space to store the Encyclopedia Britannica) or 8.6×10^{10} bits of digital information on a 12-inch disc." 67/ He estimated in 1979 that such a system might cost $1,200 by 1984.

Within agriculture, uses of videocassettes and videodiscs are likely to show growth among educational institutions that help producers (and future producers) learn. Given current costs for equipment and programming, however, relatively few producers are likely to invest in such systems during the near future.

9. Print media

Some dramatic changes are occurring in print communications directed toward farmers and ranchers in the U.S. The following are some recent technology-based changes, plus emerging or potential developments.

a. Gathering specialized reader-groups.

Publishers and others are using several methods to get agricultural information to increasingly-defined clusters of producers.

--Some commercial farm publishers are using free-controlled circulation as a means of reaching all of (and only) the producers who meet certain geographic, demographic, economic or other criteria. The practice of sending commercial farm publications to producers without charge emerged in about 1915 and increased slowly until the mid-1960's when it showed rapid increase. By 1970, nearly 17 percent of all U.S. commercial farm periodicals were distributed by free-controlled circulation. 68/

--Emergence of periodicals published by farm organizations represents another means being used to get information to specialized groups of producers. At the turn of the century, only about three percent of all commercial farm periodicals were published by farm organizations. By 1970, nearly 46 percent were published by farm organizations. In effect, these periodicals formed a new print channel for reaching certain groups of producers.

--Direct mail is finding increasing use by marketers of farm supplies and services, educational institutions and others. Franking privileges have helped extension services use mail to reach specialized clientele.

--Whereas newsletters have long been popular as an information channel used by extension services, numbers of commercial newsletters for farmers have increased markedly during the past decade. Their use is likely to grow further, in the face of pressures discussed earlier.

b. Toward individualized copies of publications.

Farm publications are pioneering in a concept aimed at giving each subscriber an individualized issue, with content tailored to that producer's specific site and needs. The most ambitious effort to that end is being exerted by Farm Journal magazine which has earned the label, "the most complex magazine made." The October, 1979, issue, for example, was actually 374 different magazines, based on different editorial versions and advertising buys. One of the technologies that makes this possible is an experimental binding system which the printer, R.R. Donnelley, calls selectronic binding. A reading head transmits instructions from the subscriber's address label to the various stations on the bindery needed to make up that particular reader's copy. This remarkable concept brings with it major potentials for improving the kinds of information a particular farmer or rancher receives through a farm publication.

c. Print reference services.

Recent years have brought some increase in reference services to which farmers and ranchers subscribe for current information. These services often take the form of notebooks that contain subject matter sections of information sheets. Some of the existing reference services are offered commercially, others by public agencies such as extension services.

This concept is appealing in that it helps the producer assemble an at-hand, current set of references which are retrievable, by topic. However, it has not become widely used in the U.S. Agricultural information suppliers in some other countries are developing the concept more aggressively. For instance, several of the state departments of agriculture in Australia have introduced a fact sheet system modeled on a system widely used in New Zealand and Canada. The one- to two-page fact sheets, punched for use in a ringbinder, deal with specific subjects on a "how to" level. Each fact sheet is indexed according to the Agdex system, a six-digit, hierarchical, color-coded index.

The fact sheet system offers several advantages over the traditional printed extension materials such as bulletins, circulars and magazines. It can generate a wide range of highly specific information pieces more quickly and at lower cost. Information in those pieces can easily be filed, retrieved and replaced as revised. On the other hand, such systems may require more effort (in filing fact sheets) than the producer/subscriber wants to invest, and without such effort the system fails. Charges for such services also meet resistance among producers accustomed to receiving farm-practice information free or at low cost from private and public sources. Another possible limitation is that general-type reference services provide information about some topics of little interest to a given subscriber. At the information-supplier end, a reference service requires constant effort.

Print reference services probably will increase in popularity and use, especially as they become more specialized and flexible in what a given producer can choose. They also fit smoothly into the trend toward more formalized programs of continuing education for farmers and ranchers.

d. Electronic publishing.

Earlier descriptions of home information services have touched on this emerging development facing publishers. For example, current newswire and newspaper items already are available to users of "The Source" information service. Some major daily newspapers are "going electronic," experimentally, by joining a national computer data network which Associated Press and the CompuServe Information Service are assembling. Developers have their eyes on home computers, viewdata and cable systems as means for getting their news materials into homes and offices. To illustrate, with the network mentioned earlier, anyone with a computer terminal will be able to receive news from a given newspaper by telephone coupler at a time-sharing fee of $5 an hour, billed in one-minute increments. 69/ Newspapers receive 20 percent of that charge. 70/ The nation's first "electronic newspaper" went into operation in Columbus, Ohio, during July, 1980, offering viewer/readers almost all of the paper's editorial matter.

No farm publishers are known to be involved in electronic publishing at present, but some are examining the technology.

Benefits of instant access to news are apparent to users of such information services. Publishers see them as possible ways to reduce printing, postal and other costs. However, some limitations of electronic publishing already are clear, and others will appear. Information which reaches the reader on a screen is less portable than that in a newspaper. Screen-reading of electronic pages is much different, psychologically, from the process which readers often use as they browse, skip, re-read and roam their way through their newspaper. Also, current limitations of the electronic technology in reproducing graphics leave it far from re-creating today's newspaper. Underlying all are the uncertainties of cost and consumer acceptance.

Within agriculture, electronic publishing concepts may find their best early applications in directories, catalogs, classified advertising, prescriptive and othe uses that require retrieval from large bases of rapidly-changing, textual informati for which users are willing to pay.

G. Public policy issues and concerns

Even though most of the communications technologies discussed here are new, and even rudimentary, they are much farther advanced than is our society in its ability to assess and use them. New technologies, in general, often seem to offer more than they deliver. U.S. Senator Ernest Hollings echoed this frustration in 1977 when he introduced a hearing about rural telecommunications. In referring to the use of new information systems to deliver medical and other services in rural areas, Senator Hollings noted: "In view of the high promise of such innovations, the reality of their actual use has been disappointing." 71/ Similarly, educators have observed that instructional technology has produced no miracles during the past quarter-century.

One can respond to such experiences by belittling and rejecting new technologies. A more promising approach involves working on both fronts -- the societal front and the technology front -- together.

Following are some of the societal issues that face policymakers concerning information systems to support the productivity of land.

1. Slow access to cable connections. To what extent will farmers and ranchers be placed at a disadvantage by lacking access to cable connections which, for economic reasons, are moving more slowly into rural than urban areas? This question has received, and should continue to receive, attention from policymakers.

2. Threats to farm television programming. What will be the effects, if any, of pay television upon the present commercial broadcasting system which currently provides producers with agricultural information? Farmer organizations have expressed concern that cablecasting of programs for which a per-program or per-channel charge is made will impair free radio and television broadcast services to rural areas by reducing the revenue (and programming) of local broadcast stations.

3. Equitable access among farmers and ranchers. Among producers themselves, who gains and who loses (if anyone) from the information methods and media that are emerging? The practice of distributing farm publications by controlled circulation offers an example. Such publications go without charge to some producers, usually those who have larger operations. However, such publications are not available to producers who fail to meet the specified standards of size of operation. Does such a system widen the gap between knowledge levels (and thereby productivity) of larger and smaller producers? Or is enough information available to small producers from other sources to relieve concern about the effects of controlled circulation?

Movement by extension services and others toward user-pay information systems raises the same question of equitability. Do such systems place smaller, less affluent producers at greater disadvantage and thereby reduce over-all productivity of land?

On the other hand, it is possible that television-based technologies may work to the advantage of the less affluent farm families, which tend to watch more television than others. Experiments with direct satellite broadcasting to farmers in India showed that free television by satellite reached those who were hard to reach by traditional educational methods.

Equitable access to agricultural information may hinge, increasingly, on the development of information systems tailored to specific categories of producers, including part-time and smaller producers. Public policy can help assure their development.

4. Involvement by users. This analysis has described some new technologies which offer two-way, interactive communications. Those interactive potentials can be achieved only when participatory qualities are built into such systems. What mechanisms within the programming organizations can help assure that farmers and ranchers, themselves, are actively involved in choosing and evaluating the informati conveyed? They can vote with their dollars in some of the user-pay information systems, but in others be left uninvolved by centralized bureaucracies. Experiences in all parts of the world emphasize the value of grassroots involvement and local control, whatever the technology.

5. Free-expression issues. The legal status of print media has traditions somewhat different from those of broadcast media. The latter operate under greater regulation because the broadcast spectrum has been thought of as physically scarce and the airways as a public rather than private good. What will be the legal effect of a merging of print and electronic technologies. Will print media come under greater regulation? Or, instead, should regulation of electronic media move toward

First Amendment laissez faire principles under which the print media operate? Should, in fact, electronic media be deregulated as some suggest?

These questions move far beyond agriculture in scope, but the type, diversity, operations and content of information systems for producers will be influenced greatly by answers that emerge.

6. Public funding for agricultural information. Inflation, limited budgets and other economic pressures are facing schools, extension systems, government agencies and other public bodies that provide production information to farmers and ranchers. How much and what kinds of financial support should the public provide for what kinds of new or restructured information systems for producers?

7. Institutional constraints. How can these public bodies overcome institutional and operational barriers that weaken their communications efforts? For example, a recent study by the U.S. General Accounting Office showed that weather service information is not being effectively communicated to users and potential users in the agricultural community. The report recommended clarifying the roles of various Department of Agriculture and Department of Commerce units involved in the Agricultural Weather Service Program. 72/ Such organizational challenges are typical at all levels.

8. Better information for producers. Many observers have noted that producers need more and better information than is available to them now. Some have listed specific information that should be developed. Greatest demand probably will appear in topics that bring greatest risk to producers - topics such as weather-related hazards, prices and supplies of inputs, diseases, insects and water supplies. Apart from greater amounts of specific information, producers in the future will need information that is more accurate, timely and interpretative. Who will generate these new kinds of information? What funding will make them possible? To what extent should the cost be borne by the public and to what extent by producers themselves?

9. Linking agricultural information systems. This analysis concentrates on systems through which U.S. farmers and ranchers get information to improve the productivity of land. How do (and should) such systems relate to others in agriculture? Researchers have noted that "any comprehensive review of our most recent efforts in rural development policy, land policy, and food policy would reveal opportunities for enhanced interaction and integration." 74/ What kinds of linkages can be created to do so?

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Background Paper No. 11

LAND USE PLANNING TECHNOLOGIES APPLIED TO CROPLANDS AND RANGELANDS

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1. Introduction

One of the fundamental resources of this country is the productivity of the land. Productivity is a function of both the yield per unit of land and the amount of land in cultivation. Advances in agricultural technologies in past decades have provided substantial increases in the yields received from given parcels of land. However, the maximum attainable yield per unit of land is not unlimited, and the rate of increase of production has slowed. Therefore, the factor expected to influence productivity the most in coming decades is no longer the yield per acre, but the number of acres devoted to production (Davies, 1979). At the same time, the needs of the public require increased use of lands in areas other than agriculture. In particular, urban expansion and land use for energy related needs have, and will continue to, infringe on the amount of land available for cultivation. As these demands on land resources increase, the need for improved land planning and management becomes more apparent.

Meeting the diverse and growing needs of the public within a limited environment is a challenging task for the future. Success at this task will depend on effective land management and the ability of planners to allocate lands appropriately to a wide variety of uses. In most instances, these land uses have requirements for different combinations of physical characteristics of the land. Appropriate matching of lands having certain properties with uses requiring those properties will be an important step toward successful land use planning. One factor that will affect the ability of land use planners to allocate lands appropriately to different uses will be the information about the pertinent physical characteristics of the land available to them. There are several technologies of primary importance involved in providing information concerning the physical characteristics of the land. The purpose of this paper is to assess these technologies as they relate to cropland and rangeland problems and issues in particular. These technologies, identified as the "most portentious new and emerging land use planning technologies," fall into three primary categories:

1) remote sensing;
2) maps of the physical environment;
3) computer mapping and information systems.

Land use planning is a relatively new field; it has been implemented in areas where demands on the land are greatest, usually urban and suburban areas. Land use planning with regard to croplands and rangelands has not been extensively practiced, but will become increasingly important in the future as agricultural lands are threatened with conversion to competing uses. Effective land use planning will play an important role in buffering adverse affects to productivity. Therefore, many of the land use planning technologies to be addressed in this report merit consideration even though they have not been extensively applied to croplands and rangelands as yet.

The organization of this paper accentuates the different levels at which these technologies provide input to land use planning and management. Section 2 provides an explanation of the fundamental concepts of remote sensing. The basic types of data used in remote sensing, their methods of processing, and an evaluation of their extent of development and use are discussed in this section. This section is first because remote sensing is one of the fundamental data sources from which a major portion of land use planning information is derived. Section 3 deals with maps of the physical environment as they relate to land use planning. Particular attention will be given to the data sources used in their creation, and the information they contribute to planning for cropland and rangeland uses. Section 4 evaluates the use of remote sensing for land management objectives other than land use planning. Section 5 is concerned with Computer Mapping and Information

Systems. At this time, the primary role of this technology is to store and display information needed for land use management and planning; an appreciation for the importance of this role will develop while reading the preceeding sections. The report concludes with a discussion of factors expected to influence the future use and development of these technologies.

2. Remote Sensing

Remote sensing is the process of extracting information concerning the nature and extent of various objects and their configurations, usually on the earth's surface, through measurements of electromagnetic radiation received by a sensor at a remote location. Perhaps the simplest example of remote sensing is air photo interpretation, in which a trained person interprets a photographic image of light reflected from a surface and imaged by a camera system. For the purposes of this report, remote sensing will refer to data acquired from cameras and other electromagnetic energy sensors on aircraft or satellite platforms for use in inventorying, mapping, and monitoring earth resources.

Remotely sensed data can be considered "raw data" because they are initially only direct measurements of certain electromagnetic properties of the landscape. Such data are usable for some applications in a raw or unprocessed form. However, remotely sensed data are generally most useful after being processed into information, typically in the form of enhanced images or as maps.

Maps derived from remotely sensed data convey either qualitative or quantitative data, or some combination of both types, about an area. Maps of qualitative, or categorical, nature are referred to as thematic maps. A good example of a thematic map is a land cover map, in which the types indicated might be urban, industrial, agricultural, forest, or pastureland. The other alternative is a map predicting a quantitative measurement of a specific characteristic for each location on the ground. Such a map is referred to as isoplethic. An example of an isoplethic map is a topographic map, containing lines of equal elevation. In addition, there are a wide variety of maps derived through remote sensing which combine some characteristics of thematic and isoplethic maps in a single map.

Remotely sensed data will be generalized into two basic types based on the format of the data: photographic images and digital images. These two groups of data are different with respect to their methods of information extraction, the extent of their use, and the level of development of their technology.

2.1 Photographic Images

Photographic images in remote sensing are simply photographs, usually taken from an aircraft, and are thus referred to as aerial photographs or air photos. Air photos have the desirable attribute of allowing the user to see large areas at a time from the unusual perspective of being in the air. This perspective is particularly advantageous when the spatial distribution of ground phenomena is of interest.

Air photos have a wide range of scales, view angles, and spectral response properties. There is a tradeoff between the size of the area covered by the photo and the level of information that can be reliably extracted from it. Small scale photography (around 1:500,000 in scale) allows examination of large areas with only very general interpretation. As the photographic scale gets larger, the area on individual photos is reduced, but the level of reliable interpretation becomes more specific. For this reason, some applications of air photo interpretation require photography at scales as large as 1:24,000 or 1:12,000.

Air photographs are taken from a variety of view angles. Most air photos are taken from a vertical view angle, keeping the spatial distortion in the photo to a minimum. Figure 2.1 presents an example of a vertical air photo showing landslides in West Virginia. This characteristic is particularly important for applications aimed at mapping, or requiring quantitative measurements of ground phenomena. However, oblique air photography, or air photos intentionally taken from an other than vertical angle, are sometimes more appropriate than vertical air photos. Oblique photos are particularly helpful in identifying topographic features and thus are often useful for geologic applications. Figure 2.2, an oblique air photo of unreclaimed mined land in Oklahoma illustrates the value of oblique aerial photography for viewing topography.

There are a wide variety of films used in aerial photography which record radiation in many different spectral ranges. The films most commonly used are sensitive to light in the ranges visible to the human eye. One major exception is the use of infrared and color infrared films, which are particularly effective for use in work concerned with vegetation.

2.1.1 Information Extraction. Information is derived from air photos primarily by manual interpretation. In this process, the interpreter assigns characteristics to areas based on the properties of the photo in that location. To assist the photointerpreter, there are a variety of techniques for making quantitative measurements of ground phenomena from aerial photography. These techniques are collectively referred to as photogrammetry. The three primary data sources available on aerial photography for discerning characteristics of a given area are tone, texture, and terrain.

The use of tonal data for photo interpetation is based on the assumption that different objects on the ground will have different tones on the air photo. Thus it follows that the spectral characteristics of the photographic image and the phenomena of interest on the ground will influence the ability to differentiate ground types effectively using tonal data alone. On black and white air photos, tonal differences are reduced to different gray tones, limiting the value of tone for differentiating ground types.

The term texture refers to the spatial pattern of tones on an aerial photograph. Different objects on the ground often have different textures which can assist in type discrimination. For example, agriculture and natural vegetation may have similar tones, but usually have very different textures. Agricultural lands tend to be relatively uniform in texture, whereas natural vegetation is often very irregular in texture due to small openings and changes in vegetation.

The use of terrain data on aerial photos can be through either direct or indirect viewing of topography. Topographic variation may be viewed directly when overlapping photos of the same area are available. When these photos are viewed with each eye focusing on the same location on different photos, it is possible to see the land surface in three dimensions. Figure 2.1 shows overlapping photos, or a stereo pair, which can be viewed on three dimensions. The ability to see topographic variation on air photos usually enhances the ability of the photointerpreter to identify objects and differentiate types.

Indirect viewing of topographic variation can often be accomplished by correlating changes in the characteristics on the photo with changes in topography. In this method the photointerpreter cannot actually see the terrain on the photo, but is still able to locate changes in topography, such as ridges and valleys, through shadowing effects or other indirect methods.

2.1.2 Development and Use of Air Photo Technology.

The use of aerial photography for mapping of ground phenomena is a well-developed technology that has been in use for a variety of applications for over fifty years. The technologies related to aerial photography have been evolving and improving during that time. Improvements in aircraft, cameras, films, film processing techniques, and photogrammetric methods have contributed greatly to the usefulness of aerial photography. However, few major new innovations are expected to increase the usefulness of aerial photography drastically in the near future.

Aerial photography is used by a large number of agencies for a wide variety of purposes. Use of aerial photos is commonplace in most agencies concerned with natural resources. Aerial photography is particularly well suited to projects involving mapping. At this time, most mapping projects of the Federal Government and private agencies use air photos in some form to assist in their work (Fitzgerald, 1979).

2.2 Digital Imagery

The term digital image is derived from the nature of recording and transmission of the image. For digital imagery, an electromagnetic sensor is used to record the amount of radiation reflected, emitted, or transmitted from a given location on the ground. Thus, each ground location will have associated with it a number indicating a measurement of radiance, rather than a density on a photographic emulsion. In this respect, a digital image is a large matrix of numbers, with each location in the matrix corresponding to a location on the ground.

There are a wide variety of sensors that record many different kinds of digital imagery. However, digital imagery from the Landsat satellites is by far the most commonly used for applications related to agricultural and rangeland management and planning. The announcement by President Carter, in November 1979, that the Landsat satellite system will be shifting from an experimental to an operational program in the 1980's helps insure that Landsat data will be available in the future. To further understand the implications of digital imagery for land use planning and management it is necessary to discuss several important related concepts: spatial resolution and spectral resolution.

2.2.1 Resolution. Spatial resolution (or instantaneous field of view) refers to the actual size on the ground of the individual picture elements (pixels) making up the digital image. Spatial resolution influences the level of information that can be extracted from the image about a phenomenon. For example, the Landsat MSS has a spatial resolution of about 56 by 79 meters, or about 1.1 acres. This spatial resolution is too coarse to allow inferences about individual trees, because there could easily be more than one tree on an acre of land. Instead, inferences can be made about the characteristics of an acre of land on a collective basis. For example, we can characterize a pixel as having a certain percentage of forest cover. Understanding this concept of spatial resolution and its implications concerning what can be called the scale of inference is central to understanding both the limitations and the strengths of remote sensing.

Another characteristic of digital imagery is the spectral resolution of the data. Depending on the characteristics of individual sensors, different types of digital imagery will have different spectral characteristics. The Multispectral Scanner on Landsat, for example, provides four separate bands of data representing reflected radiation in the following wavelengths:

0.5 - 0.6 μm	Channel 4
0.6 - 0.7 μm	Channel 5
0.7 - 0.8 μm	Channel 6
0.8 - 1.1 μm	Channel 7

Thus, there are four numbers associated with each picture element in a digital Landsat image, one for each of these channels. These data are usually stored a layered structure, in which each layer represents all the measurements in an individual spectral band.

These layers are analogous to pictures of the same scene as seen through different filters. The multispectral nature of these data helps distinguish between ground objects or phenomena that have reflectance characteristics which vary by wavelength. Vegetation, for example, absorbs radiation in the red band and is characteristically dark in that band. Since red light is absorbed, vegetation appears green, or light in the green band. The use of Landsat MSS data for vegetation classification will be treated later in the report.

2.2.2 Information Extraction. There are several reasons that can make digital image data inherently more valuable than aerial photography for particular applications. The main advantage is the ability to use computers to process the digital imagery. Digital image processing typically allows larger areas to be processed in a given time period to yield the desired information than would be possible by manual interpretation. As a generalization, digital image processing requires far less analyst input than manual interpretation. Also, due to the standardization of decision processes in digital image processing, inconsistencies in manual interpretation can be minimized.

There are two primary ways in which information is extracted from digital images. The first method involves processing the digital image into a photographic product very similar to the photographic images previously described. Following processing into a photographic product, digital images can be considered similar to photographic images in terms of methods of information extraction. Digital images however, can be enhanced prior to being processed into a photographic product. For image enhancement, certain spectral ranges can be highlighted relative to others. This enhancement often helps provide an image which is easier to interpret visually.

The second approach to information extraction from digital images involves classifying the scene into categories using digital image processing. Classification is accomplished by assigning each picture element to a class or category (e.g., a particular crop or land use) based on its spectral characteristics. Figure 2.3 is a land cover classification for Rolette County, North Dakota, which is derived from Landsat imagery using computer assisted digital image processing techniques. There are a wide variety of classification approaches, and they are collectively referred to as pattern recognition algorithms. The automated classification of digital images through the use of pattern recognition algorithms has the most potential for providing needed natural resources information for large areas in a timely fashion.

2.2.3 Extent of Development. The use of digital remotely sensed data is currently in an early stage of development. The use of digital imagery for earth resources inventory has received serious attention only since the launch of the first Landsat satellite in 1972. Substantial progress has been made since that time, but there are still many unexplored approaches to digital image processing that will greatly increase the ability of digital imagery to be used in the future.

There are several parallels between the level of development of the use of digital remotely sensed data at the present time and the development of aerial photography in the 1930's. In the 1930's, the advent of the airplane as a viable technology made available large amounts of aerial photography for the first time. This photography was from cameras and processing techniques which were crude by present standards, and the techniques of photogrammetry were just developing. Thus, the use of the aerial photography was restricted to a small number of applications. However, World War II stimulated interest in aerial photography as a military intelligence source.

Photogrammetric techniques, cameras, and films were all greatly improved, increasing both the quality of data and their usability. After World War II, aerial photography spread to nonmilitary applications to such an extent that its use has become commonplace.

The development of the use of digital remotely sensed data may follow a course similar to aerial photography. The recent development of earth orbiting satellites carrying electromagnetic sensors has made available large amounts of digital imagery that is potentially useful for resource management purposes. Similar to the past development of new films and cameras, new sensors and satellites will eventually provide vastly improved data. Also, the development of computer digital image processing techniques can be compared to the past improvements in photogrammetric techniques. In time, most manual photogrammetric methods of information extraction will be replaced with computer automated techniques that afford increased speed and accuracy in data processing. In the field of pattern recognition, in particular, innovative approaches are expected to solve problems limiting the use of presently available Landsat data.

The increased demand for natural resources information will provide a motivation for the development of digital remote sensing technologies similar to the role of World War II in the development of aerial photography. As the need for current, accurate information about a wide variety of characteristics of the land for large areas becomes more critical, increased attention will focus on the development of the necessary technologies.

3. Maps of the Physical Environment

This section provides a description and evaluation of maps of the physical environment as they are used in land use planning. Most present applications of the maps discussed in this section are in land use planning, which is related to agricultural land management through the land allocation process. More direct applications to agricultural management will be discussed in the following section. The treatment is divided into two parts, based on the level of development of the techniques used in creating the particular type of map. The first part deals with categories of maps of physical phenomena which are produced by well established techniques. Many of these techniques use remote sensing in its simpler forms (manual interpretation of air photos) augmented by field checking or sampling. The second part of this section describes maps produced by newer and emerging techniques. Digital satellite imagery is the most common data source for maps in this section, which is principally concerned with land cover maps. Methods of combining previously developed maps to create new maps of characteristics not directly measurable will also be examined.

3.1 Maps from Well Established Technologies

Historically, the agency that has been the primary producer of maps and data about the physical environment has been the United States Geological Survey (USGS). The USGS was established in 1~~9~~879 by an Act of Congress to consolidate four earlier organizations which had been doing topographic and geologic mapping (Quinn, 1979). One of USGS's more important missions is to map the topography of all fifty states and to keep those maps updated. Since this cannot be done at one time, the States assist by defining their most pressing mapping needs and entering into cooperative programs to help accomplish the mapping (Hagan, 1979). (Forty-nine states and Puerto Rico have State Geological Surveys; Rhode Island does not [Slaughter, 1979]).

As environmental resource management has become a necessity, many of the State Geological Surveys respond to the needs of other agencies for information about physical characteristics of the land. Thus, they produce maps for various regional and local planners about the geology, soils, topography, and water resources of an area. Some of the techniques used in producing these maps of the fundamental characteristics of the land and their usefulness for agricultural land management will be discussed below. This is not an exhaustive, but an exemplary list of the types of maps most commonly produced by these agencies.

3.1.1 Environmental Geology. The term "environmental geology" was coined by the Illinois State Geological Survey in 1965 and refers to the application of geological concepts and data to problems posed by human occupancy of the land and use of its resources (Jack Simon, personal communication). Presently, many of the geological surveys produce environmental geology maps and reports that are in a form and language understandable to the non geologist for use in environmental decision making. Often environmental geology maps are of geological hazards such as landslide-prone areas and earthquake faults. These products are important for planning the location of highways, power plants, or sites for solid waste disposal. Often these maps are not directly useful for land-use planning related to land productivity issues. Increasingly, however, maps are being produced of other geologic phenomena more pertinent to agricultural land management. For example, bedrock and surficial deposits maps are being produced with labels which are simplified for use by nongeologists.

Geologic maps of bedrock and surficial deposits are made by delineating the extent of substrate types on either aerial photography or topographic maps concurrently with extensive field checking and sampling. With knowledge of the geologic processes that shape the earth, maps of features beneath the surface can be inferred.

3.1.2 Topographic Maps. Topographic maps usually employ a specific method of mapping relief -- isoplethic lines of equal elevation (contour lines). These are produced by the USGS from aerial photography using photogrammetric techniques first introductd at the USGS in 1928 (Fitzgerald, 1979). Prior to that time, topographic maps were made by surveying from the ground, which is a slow and costly process. Thus, the advent of aerial photography and photogrammetry has greatly increased the scope and accuracy of the topographic mapping in this country. Topographic maps are used for innumerable applications, and they are one of the most fundamental resource maps available. Figure 3.1 is a shaded relief map of Nebraska, produced by photographically reducing USGS 1:250,000 topographic maps.

Topographic maps at the 1:250,000 scale are being scanned by a computer process by the USGS to create digital terrain tapes. These digital terrain tapes contain digital images of elevation values which can be used in computer information systems and processed with digital image processing techniques. These tapes are available through the National Cartographic Information Center in Reston, Virginia (Thompson, 1979). Figure 3.2 is a digital terrain image of the Goosenest ranger district, Klamath National Forest, California, produced by digital image processing techniques and enhanced to simulate shaded relief.

A slope map, which is derived from a topographic map, is generally the most useful form of topographic map for agricultural land use planning purposes. Slope maps show the percentage, or steepness, of the slope and can be derived from topographic maps either manually or by an automated technique. As an example, a color-keyed slope map produced by the Nevada Bureau of Mines and Geology using a computer-based comparison of contour interval spacing is shown in Figure 3.3.

Slope maps are useful in land-use planning for agricultural and rangeland applications, because the suitability for cultivation is related to the slope. Also, slope is an important variable for consideration in areas where soil erosion is a factor. One specific example of the use of a slope map in land-use planning concerns lignite surface mining in Louisiana. Slope maps were used to determine the acceptability of a location for surface lignite mining. Slopes below 10 degrees were unacceptable for surface mining, because these represented areas with agricultural potential. Slopes between 10 and 20 degrees were considered acceptable locations for surface mining, whereas slopes over 20 degrees were too steep for mining (E. Schwerta, personal communication).

3.1.3 Soils Maps. The mapping of soils is a lengthy and difficult process that is done primarily by the Soil Conservation Service (SCS). Information about soils is important for a wide variety of agricultural applications. Detailed soils maps are delineated on air photos, and the soil types are assigned from intensive field sampling. The labels for different soil types include indications of such factors as mineral content, texture, horizon development, and topographic situation. One important use of soils maps is in the determination of prime agricultural lands. Usually, prime agricultural lands can be defined by soil characteristics alone, making the mapping of prime agricultural lands a simple aggregation of soil types.

3.1.4 Water Resources. Knowledge of water availability is important for agricultural land planning because different uses have different water requirements. Maps relating information about water resources of an area are therefore useful in agricultural management. There are several types of water resources maps created by different methods. Maps of ground water can be made by drilling test wells, and measuring the water level in these wells. With knowledge of the elevation of these wells, the behavior of their water tables, and an understanding of the subsurface geology, a map of the water table level can be produced. Another way to evaluate groundwater is to map the aquifers (sand layers that serve as water conductors) from geologic maps; Figure 3.4 presents a geohydrology map showing an important aquifer for the Dover area, Delaware. In this approach, the depth to the aquifer is used as a surrogate for depth to the water table.

3.1.5 Involvement by the States. Many of the state geological surveys and comparable agencies provide to planners geologic information like the maps just described. The environmental geology programs in some states, such as Arizona and Oregon, for example, provide only data on geologic hazards. However, many agencies are starting to produce interpretive maps based on geologic data and in some cases water resource data that evaluate the suitability of the land for different uses. The following paragraphs provide an overview of the level of involvement of the individual states in mapping physical characteristics of the land for land use planning. The overview is presented as examples from a variety of states expected to be representative of the range of involvement of states.

The Florida Bureau of Geology is currently publishing environmental geology maps of the entire state at a scale of 1:250,000. These maps will show the common rock types occurring just below the soil zone, and present this information in such a way that it can be understood by those not specially trained in geology (S. Windham, personal communication). The Gainsville area map from this series is shown in Figure 3.5. The Illinois State Geological Survey is producing a series of "geology for planning" reports by country, employing what they call a "stack unit mapping technique" of describing surficial materials, which shows the sequence of materials to a 20 foot depth (J. Simon, personal communication). These and many other state geological surveys provide such geological information to state and local planners. Some, as the Pennsylvania Geological Survey, also assist planners with interpretation and application of these data to their specific problems (A. Socolau, personal communication).

The Maryland and Delaware Geologic Surveys also prepare information about water resources as one of their main roles. The Maryland Survey has been carrying out interpretive mapping based on geologic maps and water resource maps for the last ten years, although it is not directly involved with the relationship between geology and land productivity (K. Weaver, personal communication). In Delaware, the Survey has been interpreting maps of geology and potential for groundwater recharge for several counties and preparing reports that enable planners to predict the effects of various land uses on ground water resources. This could have obvious implications for agricultural planning and practices in counties where agricultural activity is significant.

The Environmental Geology program of the Nevada Bureau of Mines and Geology has produced folios of maps to be used in planning that go beyond simply examining surficial geology and groundwater. Each folio typically consists of ten maps and accompanying text about the geology, geologic (earthquake) hazards, physical (engineering) properties, energy and mineral resources, ground-water, soils, slope, relief, land use and vegetation of the 7½-minute quadrangles in urban areas (J. Bell, personal communication). Although Nevada is only concerned with land use planning in urban areas, these folios are a good example of multi-layered data sources about the physical environment that could be useful in all phases of planning. These folios are used manually in the format of map overlays in Nevada, which is cumbersome and reduces the usefulness of the maps. Automated management of such multi-layered data sources is the primary purpose of Computer Mapping and Information Systems discussed in Section 5.

The Texas Bureau of Economic Geology has produced a map of Land Resources for the entire State at a scale of 1:500,000. The purpose of this map is to provide various agencies in Texas with a basis for evaluating considerations that are important to the use of the State's natural resources (Kier et al., 1977). The technique used was to divide the land into "land resource units." Each unit was labeled based on its most important characteristic as defined by the creators of the map. The categories used for this map were: potential for groundwater recharge; mineral resources; physical properties (substrate type); areas dominated by biological habitat; and lands altered or created by human activity. The map, a portion of which is shown in Figure 3.6, was produced using a topographic map as a base map, and existing soil and bedrock maps supplemented with airphoto mapping. This project is impressive in its scope, since the state of Texas covers almost 270,000 square miles of land. However, the units are classified in terms of first order characteristics, and although other aspects of the units are described extensively in the tables that accompany the map, some generalizations must be made, and less detail can be included than in an overlay scheme of mapping.

The North Dakota Geological Survey provides reports on physical data for land use planning that specifically address the issue of agricultural resources. These reports deal with such topics as geological factors to be considered in constructing irrigation systems, septic systems, and sewage lagoons, and the conflicts between coal and lignite mining and agricultural land use practices. For example, in a report on Divide, McKenzie and Williams Counties, data on surficial materials, mineral resources and groundwater resources were compiled, and interpretive data on the suitablility of the land for cultivation and irrigation and the potential for groundwater pollution were produced (Brostuen, 1977). Figure 3.7 is a groundwater resource map from this report, showing the soils suitable for irrigation in green.

3.2 Maps from New Technologies

This section is concerned with maps of the physical characteristics of the land that are derived from newer, and not as well established, techniques than those used to prepare the maps evaluated in the previous section. Not only are these two groups of maps produced by technologies that are at different levels of development, but they are also concerned with different types of phenomena. The preceding section described maps of fundamental physical properties of the land, such as relief, geology, soils, and water characteristics. The maps described in this section are essentially a variety of land cover maps. These maps are all concerned with surface phenomena, but they often emphasize different land cover categories prescribed by their eventual uses. For example, land use maps, vegetation maps, irrigated land maps, and cover type maps are all land cover maps, but each is concerned with a different aspect of cover.

The land cover maps discussed in this section also have a different relationship to land use planning for agricultural land management than the maps in the previous section. The maps in the previous section, though often useful for land use planning, were not developed directly with planning in mind; the land cover maps discussed in this section, however, were generally developed for this specific application.

3.2.1 Land Use Planning Maps

Land cover maps are often produced by federal or state agencies to provide background information on land use and land cover characteristics. These maps are then supplied to a wide range of users interested in specific problems or issues. Therefore, maps produced for general land use planning must give consideration to a wide variety of land cover categories. This condition is not necessarily true for land cover maps produced for more specific applications.

The USGS considers land use and land cover information inportant for the study of many economic and environmental problems, and has initiated a nationwide land use and land cover mapping and data compilation program. A complete baseline set of information is being produced from computer processing of Landsat imagery, according to a standardized classification system developed at the Survey.

This classification system consists of different levels of detail of land use/land cover classes. For example, the first level includes general categories such as urban or built-up land, agricultural land, rangeland, forest, water and so forth. At the second, more detailed level of classification, a category such as agricultural lands is further subdivided into cropland and pastures, orchards and vineyards, etc. Third and fourth levels of classification exist at still greater levels of detail.

These maps are used for various purposes, only a few of which pertain directly to agriculture at this time. For example, the Chattahoochee River Quality Study and Modeling of Water Use in the Great Plains region has used these USGS maps to help devise policies for economical water use in a semi-arid region. This approach could have implications for crop and rangeland issues (Anderson, 1980).

Several states have become involved in producing Landsat-derived land use/land cover classification maps. The Georgia Department of Natural Resources (DNR) in a technology transfer project with NASA in 1976 classified two Landsat scenes (each 100 miles x 100 miles) to derive land cover information for the following categories: 1) deciduous forest; 2) coniferous forest; 3) wetlands; 4) pasture; 5) cultivated lands; 6) bare ground; 7) high density urban; 8) low-density urban; and 9) water. They are now establishing an operational capability in Georgia to process satellite data and will produce land use/land cover maps and statistics for the entire state. With regard to agriculture, the Soil Conservation Service is using this classified Landsat scene to determine the areas and extent of change in agricultural lands in Georgia. The land cover data on pasture crops and bare ground can be inventoried by the satellite at the time of each overpass and aggregated by watershed or county (Georgia Resource Assessment Program Newsletter, April 1978).

North Dakota also has produced a level I land use/land cover classification of the State from computer processing of Landsat II imagery under the auspices of the Regional Environmental Assessment Program (REAP), an arm of the legislative council funded by coal severance taxes. REAP recognizes baseline data as a starting point for detecting and monitoring environmental change. The Bendix Aerospace Systems Division (now a division within the Environmental Research Institute of Michigan, Ann Arbor) was contracted to produce this map. As in the Georgia example, the map could be used to provide agricultural land statistics, although it has not yet been so used. Figure 2.3 presents a portion of the map, showing land cover for Rolette County, North Dakota.

The Maryland Department of State Planning has initiated a Landsat technology transfer program to develop their capabilities to produce Landsat-derived land use/land cover classifications for input into their Automated Geographic Information System. This program is discussed more fully in Section 5 (S. Alderman, personal communication).

These examples indicate that it is often state and regional governments that bring such technologies from a research and development stage to an operational stage and apply them to land use planning problems. They also indicate that land use/land cover information detected via remote sensing is useful in agricultural planning and management, because it can provide information on the rates and patterns of the conversion of agricultural lands to other uses. It is well known that agricultural lands are being converted to other uses, but suprisingly little is known about the rate and location of this conversion.

A study was done to attempt to answer some of these questions in the fertile Oxnard Plain (Ventura County) of California, adjacent to the Los Angeles urban area. Thematic data (soils and political boundaries) were converted to a form comparable with Landsat data. Land use/land cover data was derived from the Landsat imagery, so that the amount of specific land uses within the thematic categories could be tabulated. In other words, the study determined how much land of high agricultural suitability (as defined by the soils maps) was being used for agricultural, urban, or other uses.

By comparing statistics from different dates of the Landsat overpass, generalized statistical rates of land use changes were detected. Of particular interest was the detection of change from agricultural to urban uses on the best agricultural soils. Another potential usefulness of this type of project is that by evaluating Landsat imagery from the last five to ten years, rates of conversion in that time can be determined. This information is important because rapid agricultural conversion is a relatively recent phenomenon and little is known about the rate or pattern of its occurrence.

An area for future technological improvement identified by the Ventura County study is that accurate spatial determinations of land use/land cover change are difficult to ascertain from multi-date Landsat imagery because of problems with resolution and registration. As sensor capabilities and processing techniques are improved, the value of data on agricultural conversion will be greatly enhanced, because it will include accurate maps of where the change is occurring, as well as more accurate statistics on the rate of change (Stow et al., 1980).

The Iowa State Geologic Survey has recently attained computer capabilities for processing Landsat imagery. The state legislature is now considering establishing a program that would result in statewide computer files of soil surveys. This information could be used in conjunction with Landsat derived land use/land cover data for the same purposes described in the Ventura County study above -- to monitor urban conversions of prime agricultual soils (B. Hoyer, personal communication). It is significant to note that Iowa, an important agricultural state, considers this method of using remote sensing and soils data to monitor agricultural land conversion and locations of other agricultural approaches important enough to implement at the state level. The information derived would be used to evaluate existing programs and policies and to help formulate new ones.

3.2.2 Rangeland Inventory. A Landsat-derived vegetation classification is being produced specifically for the purpose of assisting in the management of three million acres of rangeland in southwest Idaho. The U. S. Bureau of Land Management (BLM) and NASA have initiated this study to evaluate the applicability of Landsat data for the inventory and mapping of natural resources on BLM managed lands in the western United States (Dipaulo, 1979). Research is also underway at Texas A and M University, under the direction of J. C. Harlan, to use Landsat technology to estimate rangeland biomass, and therefore grazing potential, through remote sensing.

3.2.3 Crop Yield Prediction. The use of remotely sensed data for crop yield forecasting is perhaps its most significant agricultural and economic application. Agricultural forecasting refers to the practice of predicting the yield of a crop based on the area of land devoted to that crop and the average yield per unit area. According to one economic model, the yearly net loss in social well being due to each 1% crop forecasting error is 300 million dollars (Hayami and Peterson, 1972). This cost makes the social return on money invested in crop yield prediction very high (Idso et al., 1975). The United States is one of the few countries that produces and publicizes accurate forecasts of its major crops, including wheat. Because the U. S. exports wheat to many countries, timely, accurate information regarding global wheat production could have a positive affect on the U. S. economy.

In 1976, NASA, the USDA, and the National Oceanic and Atmospheric Administration (NOAA) undertook the Large Area Crop Inventory Experiment (LACIE) in an attempt to develop an improved method of global crop yield forecasting for wheat, a crop of particular economic importance. LACIE used Landsat data to identify crops and estimate the area of land they occupied (hectarage). Global weather data combined with historical agricultural data were used to forecast yields for different areas of the world. Thus, the input of remotely sensed data was, first, in the form of specialized maps showing the location and area of wheat fields, and secondly, in the form of NOAA satellite data used in yield modeling.

The ability of Landsat to provide multispectral scanner data for each point on the globe every eighteen days is a great aid to crop prediction in inaccessible areas of the world. The resolution of Landsat's multispectral scanner, approximately one acre, limits its usefulness when the field size is too small. The practice of strip fallow farming, in which wheat is planted in narrow strips, greatly reduced the accuracy of LACIE spring wheat hectarage predictions in the northcentral U. S. and Canada. This problem did not occur in predicting Soviet wheat hectarage, because wheat is planted in large fields in the U.S.S.R.

The 1977 LACIE prediction for the Soviet wheat crop was within 6 percent of final Soviet figures released six months later. A 30 percent shortfall in the spring wheat crop was predicted within 10 percent of official Soviet figures released several months after harvest. The midseason winter wheat forecast also predicted within 7 percent a 23 percent above normal Soviet winter wheat crop several months before harvest.

Applying this technology to other wheat regions of the world would be difficult. In China and India, improved Landsat resolution would be required because fields are smaller. Yield models less dependent on historical data would be required for countries, such as Australia, China, Argentina, and Brazil, for which such data do not exist.

However, the results from the LACIE project demonstrate that remote sensing can help provide information on foreign commodity production with accuracy and timeliness better than that of previous crop forecast systems. The USDA, NASA, and NOAA were sufficiently encouraged to expand their efforts to develop and evaluate remote sensing technology for other major commodities and global regions (R. MacDonald and F. Hall, 1980).

3.2.4 Water Resources Applications. Another use of land cover maps is in water resources management. Agencies concerned with managing water resources have begun to use land cover maps to determine characteristics of watersheds as well as water consumption levels by different uses. The parameters of interest for different areas of water management are reflected in the characteristics of the land cover maps.

The Oregon Department of Water Resources is mapping land use activity using manual interpretation of color infrared aerial photography and Landsat imagery. Of particular interest is an inventory of irrigated lands, used for projections of expanding areas of irrigation. This information is given to the State Water Policy Review Board for consideration in allocating water for various uses. Another Oregon project uses a land cover type map derived from digital image processing of a Landsat scene which recognizes detailed classes of natural vegetation types. This information is important for watershed management.

The U. S. Geological Survey has used Landsat imagery to identify irrigated crop lands in order to predict ground water withdrawals for areas in western states. This project was done to assist the USGS Water Resources Division in their dealings with state water agencies (L. Gaydoes, personal communication). The Department of Water Resources in Idaho also used Landsat imagery for irrigated cropland inventory to assess changes in irrigation and consumptive use by irrigation district (K. Johnson, personal communication).

3.2.5 Surface Mining. A type of land use that has an impact on agricultural productivity is surface mining of coal and lignite. There is great concern at this time that surface-mined lands be reclaimed for uses including agriculture, recreation and housing once the mining operation is complete. This concern is due to the increased need for land for all these purposes as the U. S. economy and population expand.

A federal agency, the Office of Surface Mining of the U. S. Department of the Interior, as well as several state agencies, use different types of remote sensing to monitor and inventory surface mining operations. The Office of Surface Mining is developing Landsat technology to monitor surface mines with test sites in New Mexico and Oklahoma. They also use air photos for environmental evaluation of mines in the western U. S. and the Appalachian states (A. Andersen, personal communication).

The Oklahoma Geological Survey uses air photos to identify and locate surface mining activities in each county. The areas are examined by field investigation and classified as either unreclaimed, partly reclaimed, or reclaimed. Some of the lands are currently being restored for pasture and cropland, as well as other uses (K. Luza, personal communication). The Iowa Geological Survey also monitors strip mine reclamation with color infrared photos to evaluate the success of reclamation. Success is measured by continuing productivity of the land after mining (B. Hoyer, personal communication).

3.3 Ecological Modeling

One emerging method for providing information about the land valuable for agricultural land management can be referred to as ecological modeling. Thus far, ecological modeling has been applied only rarely, but will probably be used more and more as the need for information about the environment increases. In ecological modeling, the characteristic to be mapped is inferred at each location from other characteristics of that location. Generally, ecological modeling is used for predicting the value of variables that are less tangible or directly measurable than the physical characteristics mapped by the previously mentioned technologies. Often the potentials of the land to support different types of vegetative growth are the predicted variables in ecological modeling. Land Capability, Carrying Capacity, Biological Productivity, and Timber Suitability are the variables often predicted in ecological modeling.

The underlying assumption in all ecological modeling is that there is some relationship between the variable being predicted and the characteristics on which the prediction is based. Land capability for agriculture, for example, might be predicted at a location from several physical characteristics, such as slope, soil texture, and water availability. For this example, data for slope, soil texture, and water availability are combined in a mathematical model at each point location on the digital image to predict land capability. The nature of the model used to predict the desired variable specifies the influence of each of the input variables on the final result. Using the land capability example, assume that slope, soil texture, and water availability data are divided into three categories. Thus, for each variable, at each location, the slope, soil texture, and water availability is rated on a scale of one to three in increasing order of desirability for agricultural use. A simplistic model might specify addition of the values for each characteristic at a location to yield a rating of the land capability for agriculture. In this example, the range of possible ratings is from three to nine, where nine represents the areas having the highest land capability for agriculture. Thus, a value for a variable which is not directly measurable (land capability), is derived from the combination of three easily measured physical characteristics.

In the past, ecological modeling has been accomplished using manual map overlay techniques. However, map overlay techniques are time consuming and cumbersome and limit the complexity of the model determining the variable of interest. As the number of input variables increases or the complexity of the relationship between variables in the model increases, map overlay techniques become increasingly cumbersome.

More advanced techniques for ecological modeling use computer automated procedures. The Louisiana State Planning Office in conjunction with the Soil Conservation Service uses computer processing techniques to determine the suitability of the land for various uses based on soil characteristics taken from SCS soil maps. There are a large number of characteristics of a site that can be derived from the soils map labels. Different combinations of these characteristics are used to determine the suitability of the land for agriculture, pasture, and woodland. Specialized thematic maps are produced showing the suitability of the land for various uses. Since all the information used to model suitability is derived from a map with one set of labels, the computer processing essentially consists of aggregating labels into categories (E. Schwertz, personal communication).

The most advanced forms of ecological modeling involve combining characteristics from several spatially registered datasets to infer the desired variable. Ecological modeling at this level is best accomplished in a computer information system framework, which is explained in the next section. This framework also allows construction of models considerably more complex than map overlays or their digital equivalents. The full power of modeling may be involved, using common statistical methods of regression, analysis of variance and covariance, log-linear modeling, and contingency table analysis, as well as special purpose ecological models described above.

4. Remote Sensing Applications to Land Management

The preceeding section has emphasized agricultural land planning applications of remote sensing technology; this section will emphasize agricultural land management applications. For the purpose of this paper, land management applications will refer to information that can be extracted from remotely sensed data which aids agricultural management decisions within the individual farm unit. Land cover mapping and land use planning usually concern a larger area and a longer time frame than a single farm unit, whereas agricultural management as it is referred to here concerns phenomena within these units. For that reason, air photos are usually the best form of remotely sensed data for contributing information to management decisions. Digital satellite imagery, such as that from Landsat, is usually at too small a map scale to be useful, except to contribute information to regional planning decisions.

Present trends in ownership of agricultural lands favor the increased use of remotely sensed data for land management -- land units of increasing size are being owned and managed by individuals or corporations. As land ownership units grow in size, and ground observation of differences within a field due to crop stress, variable irrigation, pest outbreaks, or other problems becomes more difficult, the value of remotely sensed data will be enhanced.

Many studies are currently being carried out to test the ability of remotely sensed data to yield information about different agricultural problems, such as irrigation, pests, disease, and extremes of soil moisture. Some of these will be presented here to give an idea of the potential future applications of remotely sensed data to these problems. Also, examples of currently operational uses of remote sensing for agricultural management will be given as they exist. These operational uses are difficult to document, since users, unlike researchers, are not concerned with announcing or documenting their uses of remote sensing.

4.1 Color Infrared Photography

Aerial color infrared (CIR) photography has been studied extensively for its usefulness in the detection of disease, moisture stress and pest infestation in crops. These stresses interrupt the physiologic behavior the plant, and can be detected in the infrared (IR) region of the spectrum.

In a study conducted in Nebraska, low level CIR photography detected slight soil variations within a field which later influenced the differential response of the crop to stress. Nitrogen difficiency could also be detected, but was obscure in plots with adequate soil moisture. Moisture stress could be detected only when permanent damage began to occur in the plants (Seevers, 1979). This study showed that aerial photography has the potential to be useful as input to management decisions such as irrigation practices, nitrogen fertilizer application, and pest and disease eradication.

Aerial CIR photography was useful in Florida citrus grove management, and in the spring season prints were used to detect diseased trees. This property could be very important in containing an infestation (Blasquez, 1979).

CIR aerial photography has been used for several years to aid in problem detection in management of vineyards in the Napa Valley, California. Soil and irrigation interactions can be recognized on air photos, and, coupled with soil investigations, can lead to improved irrigation practices. Pests and diseases cannot usually be detected until the vines are irreversibly infected, but even this information has proven useful in large vineyard management. The aerial photography can show more accurately the extent of infestation and can help determine the optimum time to replace an entire block of vines. This study presents a good example of remote sensing as an operational agricultural management tool (Wildman, 1979).

4.2 Remote Sensing of Soil Moisture

The measurement of soil moisture by remote sensing has the potential to be an important tool in agricultural management. Soil moisture gives a better indication of the amount of water available for plant growth than do measurements of rainfall or irrigation, which also contribute to runoff, deep percolation, and water storage. Three regions of the electromagnetic spectrum are being studied for their usefulness in the remote sensing of soil moisture: the visible, thermal, and the radar (or microwave) regions. Each region has different associated problems, however. Cloud cover disrupts both visible and thermal remote sensing. Obscuring vegetation also makes soil moisture difficult to detect in all three spectral regions.

The implications of soil moisture sensing for agricultural management are that the growth and physiological state of plants as well as many of their pests and diseases are directly related to the availability of moisture in the soil. For example, the amount of nitrogen fertilizer needed by crops depends on soil moisture. The residence time of pesticides and herbicides in the soil also depends on moisture, for there must be adequate moisture to support the bacterial population in the soil to degrade the pesticide. Thus, remote sensing for rapid assessment of field moisture could indicate to farmers when pesticide, herbicide and fertilizer applications were most desirable. Soil moisture greatly influences the growth and survival of soilborne plant pathogens, such as fungi. Remote sensing of soil moisture could indicate where disease outbreaks are likely to occur.

The water content of the soil is an important factor in the development of insects that spend part of their life cycle in the soil, such as the desert locust. Global remote sensing of soil moisture could detect breeding areas, and the insects could be baited with poison in their wingless stage, thus avoiding the use of dangerous airborne pesticides to prevent the devastation of crops by these insects. Since they typically breed in uninhabited areas, there is little vegetation to interfere with soil moisture detection (Idso, 1975).

5. Computer Mapping and Information Systems

Computer mapping and information systems are a newly emerging technology for the storage, processing, retrieval, and display of spatially referenced data. Because they emphasize spatially referenced data, computer mapping and information systems are usually referred to as Geographic (or Geo-based) Information Systems (GIS). Geographic information systems are a rapidly evolving and potentially very powerful tool in the field of land resource planning and management. GIS's represent a technology destined to automate a large number of time consuming and expensive manual processes involved in map storage, creation, and manipulation. In addition, GIS's make map data more useful by making possible new methods and models for combining data sources as well as improving the speed of their display.

The motivation for the creation of geographic information systems has come from several directions. The need for increasing amounts of information about the land, which are required before prudent decisions about land use and management can be made, has inspired interest in new methods of data storage and retrieval, Also, as more complex environmental relationships are understood, it has become apparent that data concerning different aspects of the physical environment are used more effectively in combination than separately. Another major impetus to the creation of geographic information systems has been the desire to integrate land resources data, derived from digital remotely sensed data, with maps derived from other sources.

The major thrust in the development of geographic information systems in the near future will be in the processing of data layers. The concept of a data layer is fundamental to understanding geographic information systems. A data layer refers to a spatially registered data source containing information about characteristics of an area. Data layers typically include layers derived from remote sensing as well as maps of the physical environment. Data layers can also contain spatially related political or economic information, such as census tract boundaries and characteristics, which are not necessarily derived from the actual physical characteristics of the land.

One key issue in geographic information systems is the format of stored data layers. There are two principal formats in which data layers are stored and processed: polygon files and raster files. A polygon file consists of x, y coordinate pairs which when connected by lines, delineate uniform regions. Many of the maps of natural resources currently available are polygonal in nature, and can easily be converted to polygon files for use in geographic information systems. However, computer polygon file editing and manipulation is a cumbersome and expensive technology at this time.

Raster files are similar to digital images, which were discussed in the remote sensing section. Instead of x, y coordinate pairs, the raster file consists of values in a grid format. Each value codes for a map unit or characteristic at the point in space corresponding to the point in the computer grid. Although more data are required for raster format storage than polygon format storage, the raster format is inherently much easier to manipulate. And, the full range of digital image processing techniques are available for raster format data layers. Polygon files can easily be converted to raster files through electromechanical scanning and digital image processing. However, the conversion of a raster file to a polygon file is inherently much more difficult. The difficulty arises because raster data layers are typically more complex spatially than polygon images. The most powerful geographic information systems have capabilities for storing and processing both polygon and raster files.

Another important function of geographic information systems is the ability to provide tabular statistics through information overlays. Geopolitical and economic boundaries input into a geographic system along with data on the physical environment enable the production of summary statistics, such as land use proportions and areas within census tracts, water districts, or other desired land management units. The limiting factor in producing such categorical tabular statistics is only the number of data layers available for combination.

5.1 Existing Systems and Examples

The ILLIMAP system, used by the Illinois Geologic Survey, is a computer mapping system that can construct maps of any portion of Illinois at any scale. The Survey files most of its data geographically. At some stage in every project they undertake, data are plotted on base maps. With all the geographic information stored in a computer system, the base maps needed for each project can automatically be produced quickly and accurately. Also, new information can be added at any time to the existing database. This system was designed to help the Survey present geologic and mineralogic data, although it could be useful to others outside the Survey who wish to construct maps of Illinois. The data layers it contains are political and physical coordinates, as well as other data important to the Survey including well logs, outcrop descriptions, mine records and geophysical measurements. The main purpose of the ILLIMAP system is to produce maps such as the one shown in Figure 5.1, a map of a segment of the Lake Michigan shoreline (Swan, et al., 1970).

The Maryland Automated Geographic Information System (MAGI) is a good example of a GIS that is in operational use. The MAGI system was established in 1974 by the Maryland Department of State Planning for the purpose of assisting the Department in the preparation of its Generalized State Land Use Plan. The variables contained in the database include vegetation cover and land use as prepared from high altitude CIR photography, soil groups, slope, geology, water service areas, highways and many others.

The usefulness of a system like MAGI for planning and management as it relates to productivity of the land is evident in Figure 5.2. This map shows the use of agricultural soils by combining data overlays on the soil groups with proximity to a ten-year sewer water service area (taken as a reasonable measurement of areas threatened by urban encroachment). This information was produced to help the state's Executive and Legislative Committees on the preservation of Agricultural Land assess the current trends and probable future directions of agricultural land use in Maryland.

The Maryland Department of State Planning is currently working with NASA to incorporate land use/land cover maps derived from Landsat data into the MAGI system. This addition will greatly improve the usefulness of both the GIS and the Landsat data. Unlike the more static physical variables such as soils and geology, land use/land cover information changes relatively quickly. The Landsat system has the potential to provide frequent updates of these data, thus improving the capabilities of the MAGI system to monitor natural resources. Also, remotely sensed data have been found to be more useful when combined with other data of the types already found in the MAGI system (MAGI, 1979).

Other states have implemented or are developing GIS's similar to the MAGI System. Louisiana has developed the Louisiana Areal Resources Information System (LARIS), which employs the Geographic Information and Retrieval Analysis System (GIRAS) of computer programs developed by the U. S. Geological Survey. Data layers in LARIS include: soil maps, political boundaries, land ownership, watershed boundaries and census tracts. The system is being utilized by state and federal agencies and consulting firms as an information source for planning and environmental impact studies (G. Daigre, personal communication). The Georgia Department of Natural Resources is investigating the possibility of acquiring a computer-based geographic information system to achieve maximum use of its Landsat data (discussed in Section 3) by combining them with other data (GRAP newsletter). Even in Utah, where ubiquitous land use planning has been rejected by the state, the Department of Natural Resources is developing a computer database, with Landsat processing capabilities, for use in managing the 3.6 million acres of State-owned land (W. Dinehart, personal communication).

6. Future Potential

The preceding sections have documented present uses of remote sensing and geographic information system technologies for agricultural management applications. The purpose of this section is to present a discussion of both the potential for future application of these technologies as well as the problems inherent in their development.

It is easy to envision the future potential of remote sensing and geographical information systems to provide information for decision making at the farm level. Undoubtedly, within a thirty-to-fifty-year time frame we will see large agricultural users subscribing to information systems providing data on a variety of temporal and spatial levels. Global-level, synoptic satellite systems will allow the production of accurate crop forecasts and market demand analyses as well as other predictions which will help optimize farm management. Long range weather forecasts with high accuracies will be available, influencing not only planting, cultivating, and harvesting, but the nature of the crop itself by species and variety. At a shorter time frame and for smaller areas, the manager will receive soil moisture readouts and maps of fields, including analysis of crop development and automatic stress detection. Short term weather forecasts will optimize the timing and applications of treatments to fields. In short, the information system terminal will become the agricultural manager's primary source of information, combined with experience and judgement, in the agricultural decision making process.

At the regional level, where problems involve resource allocation and planning, land use and land use change will be monitored routinely, with observations driving economic models to predict future trends and impacts of land management decisions. This information will aid planners in developing policies to encourage or discourage particular land uses for optimal resource allocation. Crop mapping, forecasting, and yield modeling will provide an important input to agricultural policy, including crop subsidies and storage planning.

Except for some aspects of crop forecasting and long range weather forecasting, all of the applications of remote sensing and geographic information systems mentioned above are within the realm of present technology. From the viewpoint of research and development, the main problems center around (1) improving the quality of the information, including its accuracy, resolution, and timeliness; (2) reducing the cost of the information to economic levels; and (3) developing the information utilization structure sufficiently to deliver the information and have it utilized by an educated user (Shelton and Estes, in press).

A problem inherent in remotely sensed data obtained from spacecraft is coarse resolution. Many users surveyed in the course of preparation of this report have indicated a need for digital imagery with a resolution considerably finer than that of the Landsat series. To some extent, these objections will be met by future satellites returning higher resolution data. For example, the Landsat D satellite will carry the Thematic Mapper, a multispectral scanning instrument producing data with a resolution of forty meters by forty meters. However, within increasing resolution come problems in both the storage and processing of much greater volumes of data. In addition, information extracting algorithms as applied to fine resolution data must inherently become increasingly complex as ground objects are resolved individually rather than in the aggregate. Thus, the need for improved resolution may in fact be obviated by better information extraction algorithms.

Another difficulty involved in integrating remotely sensed data into geographical information systems is rectification -- the process of "rubber sheeting" a digital image to conform with a particular map projection or geographic storage mode. Rectification usually requires very detailed knowledge of the path of the spacecraft or aircraft and/or the manual or automatic establishment of correspondence points between the digital image and the ground. Many technical issues are involved in this process; for the purpose of this report, it is sufficient to say that current processing technology has not progressed to the state where Landsat images can be delivered in a registered, rectified, and radiometrically corrected form in a timely fashion to users. However, the recent committment of the President to an operational Landsat system under NASA and NOAA underscores the depth of the federal committment to solve these problems.

Another difficulty lies in the transfer of remote sensing and geographical information system technology to the state and local user level. NASA has supported the development of sophisticated data collection systems, but users have been ill prepared to use them. Effective technology transfer requires a committment to extensive training and education of users, as well as demonstration projects and federal help in integrating these systems with user information needs. The many examples of the use of remote sensing and geographic information system technology documented in this report present positive proof that technology transfer is taking place successfully in many situations. However, these successful projects are the tip of the iceberg when considered against the sheer size of the state and local bureaucracy which could utilize these technologies.

On the whole, users appear to have an easier time adapting geographic information system technology than remote sensing technology. This occurs because users are much more knowledgeable about computers and information systems in general than they are about remote sensing. In addition, remote sensing has essentially been a U. S. federal technology, whereas geographic information systems have been developed on all levels, both within the public and private sectors. Thus, remote sensing technology is likely to follow, rather than lead, geographic information systems in development and operation.

Tied as they are to computer technology, both remote sensing and geographic information systems will continue to develop rapidly, and the United States, by virtue of its lead in the development of these technologies, will continue to set the standard for the world in these fields in years to come.

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8. Figure Captions

Figure 2.1. A stereo pair of air photographs showing recent and older landslides on a hillside, Clarksburg, West Virginia. From Lessing, P., B. R. Kulander, B. D. Wilson, S. L. Dean and S. M. Woodring, 1976, West Virginia Landslides and Slide-Prone Areas. Environmental Geology Bulletin No. 15, West Virginia Geologic and Economic Survey, fig. 59, p. 28.

Figure 2.2. An oblique air photo showing unreclaimed land previously mined for coal in Rogers County, Oklahoma. From Johnson, K. S., 1974, Description of Disturbed and Reclaimed Surface-Mined Coal Lands in Eastern Oklahoma. Oklahoma Geologic Survey, fig. 5, p. 6.

Figure 2.3. A classified Landsat image showing the land cover of Rolette County, North Dakota. From Bendix Aerospace Systems Division, Ann Arbor, Michigan, 1976, Land Cover of Rolette County, North Dakota. North Dakota Regional Environmental Assessment Program.

Figure 3.1. This shaded relief map of Nebraska was photographically reduced from 1:250,000 USGS topographic maps. From Conservation and Survey Division, Institute of Agriculture and Natural Resources, The University of Nebraska, Lincoln.

Figure 3.2. Digital terrain image of the Goosenest Ranger District, Klamath National Forest, California. From Strahler, A. H., J. E. Estes, P. F. Maynard, F. C. Mertz, and D. A. Stow, 1980, Incorporating Collateral Data in Landsat Classification and Modeling Procedures. Proceedings of the Fourteenth International Symposium on Remote Sensing of Environment, in press.

Figure 3.3. Steepness of slope for the Elko West Quadrangle, Nevada, calculated by a photomechanical process which converts distance between adjacent contours into percentage of slope. From Nevada Bureau of Mines and

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Background Paper No. 12

SUSTAINED LAND PRODUCTIVITY: EQUITY CONSEQUENCES OF TECHNOLOGICAL ALTERNATIVES

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ABSTRACT

U.S. agriculture lacks intergenerational equity. There is evidence that the American public favors a production system of small, sustainable farms. By its almost exclusive reliance on economic efficiency and conventional productivity criteria, however, current agriculture technology is biased against the social equity of small farmers and rural communities. Simultaneously, it masks growing threats to soil and water resources. Four agricultural technologies are examined --- (1) mechanized cotton harvesting, (2) center-pivot irrigation, (3) no-till, and (4) organic farming --- for their contribution to sustained land productivity and their implications for social equity. Public knowledge of agriculture as a sociotechnical system is neither supported by an adequate research base nor do current methods of social impact analysis (SIA) appear promising in bridging that gap. Focusing on social equity -- temporal and intergenerational -- is suggested as a way of strengthening the methodological and theoretical base of SIA.

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INTRODUCTION

It is the purpose of this paper to describe the social equity impacts that result, or are likely to result, from changes in agricultural technology. More specifically this paper focuses on the social effect of agricultural technologies that effect the sustainable productivity of U.S. croplands and rangelands.

In this report the distinctive emphasis on sustainable productivity is important because there are other definitions for productivity. Conventional productivity in agricultural production has meant the ability continually to increase yields while decreasing the amount of labor used in the production process. According to these criteria, the U.S. system has been extremely successful. As of the late 1970s, 3% of the U.S. population grew most of the food which fed the rest of this country and provided over 86% of the world's surplus food. Since the end of WW II, total farm output has increased by over 50%, while output per unit of labor has increased over 250%. Today a single U.S. farm worker feeds close to 50 people in contrast to 1950 when the same farm worker fed only 15 people.

However, these figures do not say whether these production outputs can be sustained, or increased in the future to meet growing food demands in the U.S. and abroad. For the purpose of this report sustainable productivity in agriculture is defined as the retention of the natural capital stock of the agricultural production process, i.e., soil depth and health, water reserves and quality, and energy stocks and options. The assumption used here is that if these natural elements are retained in the system, productivity can be sustained. But if one or more of these elements become unavailable, sustained yield productivity will be extremely difficult, if not impossible.

The concern for sustained yield productivity from the U.S. agricultural system is succinctly captured by the findings of the recently released Global 2000 Report. In the thirty years between 1970 and 2000 world population will increase by over 50% to 6.3 billion people. World food production will need to increase by 90% in the same period, yet the amount of arable land is expected to increase by only 4%. The U.S. will be called upon to play an ever more important role as a world food supplier, while the U.S. itself will be exploring the expanded use of agricultural lands for fuel production. The Report suggests that "because of this tightening land constraint, food production is not likely to increase fast enough to meet rising demands unless world agriculture becomes more dependent on petroleum and petroleum-related inputs" (Barney, 1980:16). At the same time the Report notes that the impact of expanded production, in combination with other population and resource using trends, very likely spells a serious deterioration of agricultural soils due to erosion, loss of organic matter, desertification, salinization, alkalinization, waterlogging and compaction. In addition there will be problems of air and water pollution, more frequent and severe regional water shortages and increasing costs for petroleum inputs (Barney, 1980).

Within the U.S. the ability of the production system to meet this demand, and therefore for agricultural land to sustain its productivity is affected by two key factors: patterns of urbanization and soil loss. It is estimated that, on the average, 7 to 10 million acres of U.S. agricultural land go out of production each year. One-third of this loss is direct urban conversion of agricultural land, one-third of this loss is land idled in anticipation of future urban conversion, and one-third of the loss is attributable to soil erosion (Hildebaugh, 1980; Dideriksen et al., 1979; Pimentel et al., 1976). To make matters worse, it is usually the more productive lands and soils which are lost (CEQ, 1978).

The response among Americans to foreboding projections of this nature will surely be tempered by our successful historical experience with technological innovation. The National Academy of Sciences (1975), however, has recently warned that the bounty afforded by technological improvements may soon run its course. The findings of this paper suggest that massive injections of capital-intensive technology into the U.S. food and fiber production system may in fact be masking the rise of unsustainable production, even at present levels of output, while also incurring a complex array of inequitable consequences for rural people and communities.

In addition to the term productivity, two other terms used in this report must be defined at the outset. The term technology is used broadly to mean "applied knowledge in the social and political context in which it is employed" (Bereano, 1974:6). That is, technology is not an island onto itself. Technological changes do not occur without changes in the social and political system into which a technology is introduced. Applied to agriculture, technology does not simply mean a mechanical device, such as a tractor or picking machine, but rather an entire complex or system of production. Technological changes in agricultural systems have implications for the inputs and outputs of agricultural production. The former include labor, land and capital requirements. The latter involve the quantity and quality of food and the retention (sustainability) of the productive elements of the productive process.

The term social equity is used to denote two separate but interrelated issues--equality of access to decision processes, and justice in the substantive outcome of policy action. In actual application, this term comprises equity to those in the future, intergenerational equity, and equity to those in the present, or temporal equity (Jacobs, 1980). Here intergenerational equity will mean the maintenance of the natural, capital stock of the agriculture production process. Intergenerational equity is therefore roughly equivalent to agricultural sustainability. Temporal equity will mean the fairness of policy to present persons and groups. For the purpose of this report, temporal equity specifically encompasses issues of tenure (the concentration or decentralization of control over land resources), environmental health, local economic multipliers, and the viability of local community institutions. This definition is consistent with the requirement placed on the authors of providing a social equity assessment on those people and communities likely to be living in an area to which the technology is introduced. More macro issues of social equity, such as food costs to consumers at the supermarket and impacts on foreign trade, will be mentioned in passing, but are not treated in systematic fashion.

This report is organized into four sections. First is a discussion of four cases which examine technological innovation in agriculture and the subsequent impact on land productivity and social equity. Two of the cases are on now-common technologies--cotton mechanization and center pivot irrigation. Two of the cases are on emerging technologies--no-till agriculture and organic farming. Each case contains a statement of background and history, identification of equity effects, a discussion of public policies which influence(d) this relationship, and a summary statement of the key equity issues raised by technology. These four technologies were chosen because they represent a range of technology types, with a range of sustainability and social equity impacts. Together they cover a range of geographical areas.

Second, there is a review of public opinion on the general subject of agricultural technology, agricultural productivity, and perceived social equity. Following this, there is a discussion of the methodology and application of social impact assessment. Its relevance to evaluating agricultural land productivity is presented in light of its current limitations and in light of the challenge of redefining productivity as intergenerational sustainability in productive capacity. Finally, the report closes with a general summary and conclusions. The latter highlight patterns and relationships inferred by the authors in their review of the technology-productivity-equity relationship. Several salient areas of additional research are recommended.

The Importance of Context

Every technology is embedded in a societal context. An important contextual reality in understanding why particular technologies are selected for adoption in the U.S. agricultural system has come to be known as the structure of American agriculture (USDA, 1979). The defining characteristic of this structure is the concentration of farm units, comprised in part of dwindling farm numbers and increasing average farm size and productivity. In addition to the decline of the traditional family farm, other structural changes in American agriculture include increased corporate participation in agriculture, greater vertical integration of the production process, dramatic increases in the use of fertilizers and pesticides, increased use and scale of the machinery in agriculture, and decline in the viability of local rural communities (Cochrane, 1979; Pimentel, 1978; Berardi, 1980; Goldschmidt, 1946).

Herein lies the connection between the present report and the changing structure of the nation's largest industry, agriculture. By conventional definitions of productivity, U.S. industrialized agriculture is a "miracle," a combination of extensive lands, rich topsoils, and a prodigious technology.

This technology derives from intermingled public subsidies, private profit incentives, and wartime research and development. It is this miracle of bumper crops and bounty that makes the application of ever greater technology inputs to U.S. agriculture axiomatic for many and affirms the premise that productivity defined as efficiency subsumes issues of social equity.

The charge of the present study is to put convention aside. When productivity is redefined as long-term sustainability of productive resources, including soil, water and viable human communities, the social equity diagnosis is very different. Soil erosion is today so extreme in the U.S., according to the Soil Conservation Service, that current rates must be cut in half to sustain even current levels of production (Barney, 1980). Ground and surface waters are being poisoned by fertilizers and pesticides and are being depleted by irrigation demands at rates surpassing natural recharge capabilities (CEQ, 1979). As for labor resources, former Secretary of Labor Marshall (1974) and many others link capital-intensive technological breakthroughs with massive labor displacement and myriad social consequences.

In part, these social consequences stem from differences in who is able to benefit from the introduction and adoption of a particular technology. An equity problem is whether farm size differences allow one group to capture a disproportionate part of a new technology's benefit while, at the same time, shifting burdens to other groups. The "treadmill of technology" argument is illustrative: large farmers have historically had more influence than small producers over what technological innovations were introduced to the market. The access to capital enjoyed by large producers enables them to adopt the new technology more quickly than smaller producers.[1] The advantages of increased production accruing to early adopters often forces smaller producers to adopt in order to remain competitive. Failing this, smaller producers are forced out of farming. This treadmill then repeats itself and farm concentration become structured.

The dictates of balance of payments and world food demands combined with the structure of U.S. agriculture seem to require that productivity, in its traditional sense, continues unthwarted while productivity as sustainability and social equity is sacrificed. If soil, water and human capacity are the capital stock of the future, our present agriculture may be embarked on the precarious road of deficit development. In other words, with prudent management our food production system is a renewable resource. Without such managment it becomes a non-renewable resource, technological "fixes" nonwithstanding.

CASE STUDIES

CASE STUDY ONE: MECHANIZED COTTON HARVESTING

Background and History

Automated cotton harvesting entails the use of tractors and mechanized cotton pickers to gather cotton. As with the substitution of machinery for labor in the harvesting of other crops, automated cotton harvesting is not without its social consequences. As one study noted:

> When the cotton picker was developed, agricultural intellectuals... should have studied the problems of adjustment forced on cotton field hands, should have assessed the social costs, should have devised institutional reforms to cushion the shock and the cost--a cost which should have in some way been shared by cotton producers, the cotton processing and merchandising industry and, of course, by the cotton consumers.... And partly becuase we failed to learn from that experience, we go blindly forward developing tomato harvesters, field lettuce cutters and field lettuce packing technologies, milk production factories and the thousand and one other forms of improved technological efficiencies. (Kelso and Hillman, 1969)

The present case study and those which follow attempt to reduce the blindness alluded to by examining, in historical context, the social equity impacts of selected technologies. The population of interest in the present case are the rural residents of the United States South.[2]

U.S. cotton cultivation has a history rich in invention and technological refinement. New technologies have permitted the retardation of soil exhaustion and boll weevil infestation, the redemption of marginal lands and returns on investment sufficient to maintain prosperity at least among planters and merchants (Myrdal, 1957). When the harvest itself was finally mechanized, stoop labor was widely alleviated, and children were freed from the labor force to attend school. According to authoritative observers on the eve of cotton harvest mechanization a socially beneficent transformation would entailed a broad distribution of the profits derived from conserving human labor and a sufficiently gradual pace to limit shocks of relocation and readjustment (Horne, 1937). Neither of these conditions were met in ensuing years.

Despite the revival of the southern economy following the Civil War, cotton remained labor-intensive in the extreme until the Depression (Fite, 1950; Ransom and Sutch, 1977). When automation came to cotton harvesting in the years following 1934, it was exceedingly abrupt:

> "It may even be true that though agricultural technology lagged behind industrial technology for a long time, the rate of change in farming technology over the last two decades, particularly in the South, has eclipsed anything the industrial sector has ever seen." (Lee, 1968:84)

Tractors and harvestors "revolutionized" the plantation system, converting it to modern capital-intensive farming. Paradoxically, this occurred at a time when capital was generally scarce, the market was depressed, and cheap labor abundant (Street, 1954). Given capital shortages in the 1930s, this can only be interpreted in light of public policy which altered profit incentives among southern planters.

Equity Issues

Formal analyses of the equity dimensions of cotton mechanization are largely indirect, appearing in commentaries on real property dispossession and workforce transformation and dislocation (temporal equity issues), or on regional soil exhaustion (intergenerational equity).

Intergenerational Equity:

Mechanized cotton harvesting had important consequences for soil quality. Whereas it cannot be said that soil depletion was unknown in the labor-intensive plantation system prior to mechanization, capital-intensive cotton farming does seem to have significantly contributed to soil loss and degradation.[3] The displacement of tenants and small land owners meant the removal of many of their 5,000,000 horses and mules, a major source of organic fertilizer (Horne, 1937). As tractors and mechanical equipment related to harvesting have increased in size and weight, and as they make added trips over the land to harvest and to apply new herbicides and fertilizers, soil compaction has emerged as a productivity constraint (Brooks, 1977). Despite applications of ammonium nitrate, anhydrous ammonia and other fertilizers, there is region-wide evidence that over-fertilization is delaying crop maturity and intensifying pest damage (Maples, 1977). From the standpoint of long-term food and fiber sustainability in the South, it may well be that technology substitution, instead of staving off soil infertility, is disguising the exhaustion of southern lands (Perelman, 1977).

Temporal Equity:

As regards the distribution of mechanization benefits, there is extensive evidence that the allotment system was not size-neutral, insofar as small farmers had insufficient acreage to benefit from or initially afford capital intensive cotton cultivation (Horne, 1937; Butler, 1950; USDA, 1957; Burch and Hubbard, 1969). Large planters were the principal beneficiaries, given the windfall capital that their federal government allotments generated and their sudden protection from the vagaries of both commodity and labor markets.[4] Not only did most of the benefits of mechanical cotton harvesting tend to bypass small holders, tenants, and sharecroppers, but they progressively widened the gap in assets and opportunities between large and small producers, hastened land loss among the latter and created an uprooted class of wage laborers who, often involuntarily, joined the rural-to-urban migrant stream in quest of employment (Fligstein, 1976).

The flood of wage labor thus produced had extensive social reverberations. Dislocation meant migration within and beyond the South and was associated with new skills and income possibilities for the most able. These benefits proved to be, in the final analysis, contingent on the expansionary economy during and after World War II (Street, 1957). Notwithstanding this absorbtive coincidence mitigating the displacement of unskilled field labor from the South, migration was often involuntary, spearating families and communities for reasons beyond the control of either. Nor did migration promise security, either for the new wage laborers or for the unemployed not in the prime of life. Urban destinations often proved hostile, lacking in social services and opportunity structures which earlier waves of urban immigrants had obtained (Pogue, 1979; Norton, 1980).

This widespread displacement of tenants, sharecroppers and small operators dramatically poses the close association between equity (ownership) in real property and social equity. Land ownership has long been viewed as the repository of wealth, security, status, power and even piety (Moyer, 1969). Black visionaries as diverse as Du Bois and Washington hardly deviated from American tradition in equating true emancipation and enfranchizement with land ownership. From their landless status at the end of the Civil War, blacks came to own an estimated 3 million acres by 1875 and an estimated 15 million acres by 1910 (Nelson, 1979), often at extraordinary personal sacrifice.[5]

Since 1910 black landowners have relinquished title to over half (9 million acres) of southern land holdings (Browne, 1973). Six million acres of this loss has occurred since 1950, or after the mechanical revolution in cotton harvesting had broadly diffused (Salamon, 1976). This dramatic decline in ownership assumes considerable added meaning in view of research suggesting black land tenure is positively associated with health and self-esteem (Woofter, 1930), with nutrition and access to credit (Raper, 1936), with personal effectiveness (Stacy, 1972) and political power (Nelson, 1979). Land ownership among blacks has been shown to enhance economic security and household well-being (McGee and Boone, 1976) and seems to be as useful an anti-poverty measure as others which have been tried (Salamon, 1976). Insofar as land dispossession was inherent in cotton harvest automation, mechanization caused widespread deprivation, both material and social-psychological among poor blacks who had only recently attained this measure of economic security.

If harvest mechanization shielded planters from market uncertainties, broadly defined, land tenure shielded the resident labor force from the uncertainties of wage labor status. No socially significant aspect of mechanization has received as much commentary as the abrupt dislocation of field labor of all kinds (Thomas, 1934; Spurgeon, 1936; Frey and Smith, 1936; Dickins, 1949; Conrad, 1965; Ainsworth, 1967; Grubbs, 1971; Marshall and Havlicek, 1977). The sudden emergence of this wage labor force was disruptive to labor organizing efforts, or off-farm wage levels, to standards of livings in southern communities and beyond, and to the social status of the workers themsevles.[6,7]

Government Policy

Several recent doctoral dissertations confirm the role of the Agricultural Adjustment Administration (AAA) in triggering the accelerated conversion of labor-intensive to capital-intensive cotton harvesting after 1934 (Maier, 1969;

Martin, 1972; Musoke, 1976; Fligstein, 1978; James, 1980). Through the AAA, Congress sought to arrest chronically low cotton prices by paying farmers to reduce cotton acreage. AAA allotments cut cotton acreage by approximately one-third, reducing labor requirements directly. For a variety of reasons,[8] massive substitution of harvest technologies, especially tractors, for labor followed and, contrary to the intent of the AAA, productivity mushroomed. The number of tractors on southern farms doubled between 1930 and 1940 and doubled again between 1940 and 1945; between 1938 and the mid-1960s, per acre production rose from an average of 200 pounds to one exceeding 450 pounds (James, 1980). By fostering mechanization, the AAA indirectly spelled the end of hand-picked cotton as well. In 1950 less than 10 percent of harvested cotton was hand-picked whereas virtually all cotton was mechanically harvested by 1970 (Marshall and Havlicek, 1977).

Summary

The principal social equity impact of cotton mechanization was the displacement of large numbers of tenant and small-scale farmers. This was accompanied by substantial migration in search of jobs, the decline of locally based and economically viable rural communities, and the accelerated deterioration of southern topsoils. Non-market forces mitigated labor dislocations which followed mechanization, including a variety of large-scale relief, relocation and employment programs of the New Deal (Salamon, 1976) and, in a less planned fashion, World War II. Forces mitigating the loss of land, community, and the soil have proven harder to identify.

Market forces were of course not neutral in the mechanization of cotton picking and contributed to the allocation of social costs and benefits during this process. The concentration of assets and institutional control among planters substantially predetermined who would migrate and who would remain and prosper, as well as who had the resources to diversify into non-cotton agriculture before and after 1934 (Brannon, 1968). This regional structure of agriculture predetermined what size cotton producer was likely to adopt mechanical harvesters when they appeared.[9] Market forces also meant competition with the highly automated western producers. As a final note, whereas allotments contributed to the displacement of smaller cotton operators, current allotment policies in other production areas (e.g., southern tobacco) contribute significantly to the livelihood of small operators (USDA, 1978).

CASE STUDY TWO: CENTER PIVOT IRRIGATION

Background

Center pivot irrigation (CPI) is a highly capital and energy intensive agricultural technology, currently in use in 38 of the 50 states (Servin, 1979). The diffusion of CPI in recent years has substantially added to near-term crop yields in the United States and, in so doing, has "literally moved the cornbelt from eastern Nebraska to the Rocky Mountains" (Spliner, 1979:42). The existing research and literature on the relationship between CPI and social equity is minimal. Some initial analysis has been conducted for the Sandhills region of Nebraska (Holt County in particular) and the Columbia basin of Washington and Oregon. The assessment of social equity will be limited, in general, to the case materials for these two areas.

History

CPI was one in a series of significant irrigation innovations evolving since World War II. These innovations were based upon the advent of rotating sprinkler nozzles and the availability of comparatively cheap aluminum pipe. An important feature of CPI, within the context of the historical development of irrigation technology, is that it dramatically reduces labor inputs and costs. This tremendous reduction in the labor intensity of CPI irrigation technology distinguishes it from the traditional pattern of effect of other irrigation technologies upon local communities.

In addition to automation, two other features underlie CPI's importance and adoption. First, such systems apply water frequently and lightly, thus minimizing erosion and enabling increased production on coarse textured or sandy soils which hold little water and often have minimal capacity for soil nutrients. Nutrients and other crop applications can be added to the sprayed irrigation water, and the light, frequent spraying maintains appropriate soil moisture. Second, the mobile CPI arm can also adjust to grades of up to 30%. Thus, land that is usually too costly or fragile to grade (i.e., change the slope of using heavy equipment), and thus unfeasible to irrigate by other methods, can now be productive. Studies in Nebraska (Center for Rural Affairs, 1976; Stone, 1977) and in the Columbia Basin of Oregon and Washington (Muckleston and Highsmith, 1978) point to the rapid adoption of CPI for the conversion of low grade, often rolling, sandy grazing land into productive irrigated units.

Equity Issues

Intergenerational Equity:

In Nebraska what was seen as an abundant underground water resource for CPI as recently as a decade ago is now subject to concerted water management planning. CPI has contributed to severe water table drops and "aquifer mining," depleting a non-renewable stock of water. Such aquifer mining is occurring in Nebraska, Kansas, Texas, Colorado, New Mexico and other states. According to Splinter (1979:42), "there is not much hope for recharge in many of these areas, and once the water table is depleted, it will force farmers back to dry land production." Inadequate supplies of water have already resulted in crop failures for land under CPI (Council of Environmental Qaulity, 1979). Energy use of CPI in Nebraska indicates that CPI uses 10 times the fuel needed to till, plant, cultivate, and harvest a crop such as corn (Splinter, 1977).

The use of CPI also has important implications for maintenance of soil quantity and quality. As noted above, a threat to area water flows can undermine the continued operation of CPI and the attendant increased yields. Therefore, the effects of CPI on soil erosion and soil quality are important when and if lands are returned to dryland or other non-CPI forms of production. Center for Rural Affairs (1976) notes that CPI technology has not been in use long enough to do a long range analysis of its effects on soil. They do, however, point up several important trends observed in an examination of CPI in Holt County, Nebraska.

The increase in CPI irrigated acres in Nebraska has corresponded to a drop in the percent of acres under irrigation which are arable. This is noteworthy from the standpoint of sustainability due to the landscape changes which CPI necessitates. The 8-foot high rotating irrigation arm requires the removal of many normal features of the landscape, including treelines, which aid in soil conservation. Replacement of treelines would require substantial investments in time when reversion to dryland farming becomes necessary. In the interim, during the growth of the treeline, substantial soil erosion could occur.

Another important feature is the rise of investor-owned CPI operations. Center for Rural Affairs' reserach indicates that the investors' share of the non-arable land being irrigated increased from 27% in 1974, to 52% in 1975, and might have gone as high as 67% in the following years (based upon applications for permits, etc.). The soil type in Holt County undergoing rapid development by the investor-owners was considered by the U.S. Soil Conservation Service to be "suitable only for grass, trees or wildlife..." (USDA, 1963:16). As the rapid recent growth in center pivots is increasingly investor-owned, this trend may indicate an increasing tendency toward less sensitivity to important soil and environmental characteristics. Over time this could adversely impact the sustained yield capabilities of lower quality soils. A trend which corroborates this line of reasoning is found in a recent USDA ESCS report on investment in soil conservation, drainage and irrigation in the U.S. This report's main finding was that soil and water conservation improvements are declining in the U.S. while expenditures on irrigation improvements are increasing (USDA, 1979).

Temporal Equity:

The resource intensity and the increased pattern of absentee/corporate investment are the two major sources of interest in evaluating CPI's temporal equity effects.

Size Neutrality

The effects of absentee investment mechanisms and ownership have led to increased size of land holdings and changes in tenure patterns. Some 96% of owner operators in Holt County own four or fewer pivots (CRA, 1976). Only 56% of the investor owners, on the other hand, were in this category and one investor-owned 127 pivots.

Tenure

Perhaps the most central social consequence of CPI is the change in ownership and ultimate control of land and production which has occurred because of the high-cost financial packaging, and low labor intensity surrounding or characterizing the technology. The financial barriers for the normal operator to adopt CPI are formidable. The initial capital investment can normally run well over $61,000 for a single pivot unit, and estimates of annual fixed and variable costs (1976 figures) total $46,500 per 160 acre section of corn (Sheffield, 1977:20-21). Thus, while in the early days of CPI, farm operators were the principal adopters of the technology, the situation has rapidly evolved to the point where most new investment in CPI is done by off-farm and absentee investors, who also buy land and make use of the investment to shelter income. The increase in absentee control of land and production has increased the role of hired farm labor and tenant farming where CPI is used (Center for Rural Affairs, 1976).

Economic and Labor Multipliers

The direct economic benefits of CPI are substantial. In Nebraska, CPI has increased yields of corn by 100 bushels per acre in comparison with dryland production. Using capital investment multipliers, the total economic impact of CPI investment on the Nebraska economy in 1976 was estimated to be $223.7 million (Sheffield, 1977). On-farm labor demand differs significantly from the high capital multipliers. The labor required to operate land under CPI is one-half or less the labor required to manage equivalent acreage with surface or gravity irrigation.

Community Structure and Impact

In the Columbia Basin region of Washington and Oregon, water for CPI is drawn directly from the Snake and Columbia Rivers. Here, the energy impacts are somewhat different from areas where ground water sources are used (Muckleston and Highsmith, 1978). By drawing down the flow of river water, application of CPI leads to a decrease in the generation capabilities at downstream hydroelectric plants. This lost hydro power increases demand for higher cost thermoelectric generation which, in turn, increased electricity costs to area consumers.

Moreover, since CPI uses such high volumes of electricity, it qualifies for lower rates. Whittelsey et al. (1976) estimate that the net annual cost of this rate disparity for every acre of land irrigated (in a specific region of the Columbia Basin known as Horse Heaven Hills) will be about $60 for other area energy consumers.

In its historical context, the effects of CPI irrigation on farm size and population are atypical of old style irrigation technologies. Intensification of production through traditional irrigation in Great Plains communities has kept farm size smaller and farm population larger than in non-irrigated areas (Stone, 1977). The increase in the number of CPI adopters has been concurrent with relatively rapid growth in the size of the individual irrigated farms in Holt County, Nebraska. Stone (1977) observes:

> Had there never been a center pivot machine, other sprinkler types would no doubt have eventually occupied much of the same landscape, but hardly as an attraction for an investor or an absentee owner. Investor operators would not have been tempted to farm with the smaller scale, labor-requiring sprinkler. Growth of the irrigation economy would likely have been slower, and would probably have remained in the hands of the small farmer.

These results would indicate that, in comparison with other irrigation technologies, CPI would have more adverse impacts on local community health and viability (Goldschmidt, 1978). In particular, the bias against a small farm structure would erode local economic multipliers and the viability of community institutions.

Public Policy

To our knowledge, there is no specific national public policy concerning CPI. It is noteworthy that in several states, particularly Washington, Nebraska, and Oregon, public policy initiatives have been put forth to monitor or regulate some aspect of CPI's extensive resource use. In the state of Washington a family farm act has been passed which limits permanent water rights to family owned units not exceeding 2000 irrigated acres per person in the farming family (Muckleston and Highsmith, 1978).

Summary

CPI has lead to dramatic increases in per acre production yields. These increased yields are dependent on high levels of water, energy and capital usage. Because of certain constraints on long-term water availability and growing energy constraints, it is tenuous to consider the increased yield made possible by CPI "sustainable." In certain contexts, such as the Columbia Basin of Washington, CPI has had clear adverse impacts on the surrounding region and communities. In terms of the structure of agricultural production, CPI is increasingly dominated by corporate owners external to the community, which in turn contributes to real change in the social relationship between people and land, as well as the size and distribution of farm parcels. CPI appears to have thrived on an absence of local or regional policy which would regulate or monitor the large scale appropriation of water, land and soils, and energy resources.

CASE STUDY THREE: NO-TILL AGRICULTURE

Background and History

No-tillage agriculture is one of mankind's oldest methods of crop production. No-tillage represents a family of related terms--zero-till, direct seeding, direct planting, no-plow, and spray-plant-harvest. Under a no-till system, a crop is planted either entirely without tillage or with the least tillage necessary to allow placement and coverage of the seeds with soil sufficient to allow them to germinate and emerge (Phillips, Blevins et al., 1980). No soil preparation is done other than that of opening a trench of adequate width and depth to obtain seed coverage (Phillips and Young, 1973). *No Till Farmer* magazine defines no-tillage as cultivation where only the seed zone and up to 25% of the land surface area is worked (USDA, 1975).

No-till agriculture contrasts sharply with conventional tillage practices. For centuries farmers have developed myriad practices of plowing, smoothing, and pulverizing the soil principally through use of the moldboard plow followed by several diskings. Such "complete tillage," thought necessary to control weeds, to manage field trash, to aerate the soil, and to aid normal root development, was supported by generations of practice (Phillips and Young, 1973). Fifty to sixty years ago farmers thought four to five cultivations after row planting were essential and, in all some 10 trips across a tilled field by harvest time were common (Triplett and Van Doren, 1977).

In 1943, E. H. Faulkner's book, Plowman's Folly, appeared. In the wake of the dust bowl, Faulkner criticized the plow as the basis of most, if not all, problems related to soil quality and crop production. Indeed he argued that "no one has ever advanced a scientific reason for plowing" (Faulkner, 1943). The book was both widely praised and criticized within the ranks of organized agriculture (Friends, 1943; Troug, 1944; Albrecht, 1944) and had the effect of subjecting conventional tillage to more critical evaluation. The book's most controversial proposition--that plowing was unnecessary--supported growing concern that conventional agricultural practices exposed soil to severe erosion from wind and water.

Increasing awareness that conventional tillage threatened the finite resource of soil coincided with the introduction of herbicides in the late 1940s. It was the introduction of 2,4-D in the late 1940s that proved a solution to the broadleaf weed problems in corn production. By controlling perennial weeds, herbicides reduced the need for multiple tilling operations and made reduced tilling practices more widely accepted. This chemical revolution, in conjunction with the constant market pressure to cut production costs, brought about a reevaluation of time-honored tillage practices.

Since the mid-1950s, the land area for row and forage crops in no-till has increased rapidly. In 1974, the USDA estimated that U.S. cropland under no-tillage was 5.5 million acres and that by 2000 nearly 45% of U.S. cropland will be no-tilled (USDA, 1975). An estimated 65% of the 7 major annual crops (corn, soybeans, sorghum, wheat, oats, barley, and rye) will be grown under no-till by 2000 and nearly 78% by 2010 (Phillips, Blevins et al., 1980). Thus it has been stated that,

> ...no-tillage systems of husbandry could conceivably facilitate an increase in food production comparable to that made possible by the shift from animal power to machine power in agriculture that occurred in the U.S. during the last half century. (Shear, 1968)

The potential for multicropping may well be the most important factor in no-till agriculture acceptance. Formerly considered a practice available only to farmers in the southeast, multicropping is now moving to the northern Corn Belt of the U.S. (Phillips and Young, 1973; USDA, 1975). Under no-till, harvesting of one crop can be followed by immediate planting of the next crop. Corn-small grain for silage, corn-barley for grain, corn-barley-soybeans are some combinations of multicropping possible under no-till. Getting two or more crops, although not confined to no-till, is enhanced by the reduced time required to plant following harvest (USDA, 1975). This enhanced opportunity to multicrop could also compensate for any loss in yield under no-till agriculture with certain soil types (USDA, 1975).[10]

Conventional methods of tillage require considerable expenditures of energy. Currently, about one-third of the energy used for food production is consumed in the crop production phase, that is, plowing, discing, planting, and cultivating (Phillips, Blevins et al., 1980). Under conventional moldboard plowing and discing, an average of almost 200 gallons of diesel fuel per 100 acres is not unusual. In contrast, no-till estimates average less than 50 gallons of fuel per 100 acres (Triplett and Van Doren, 1977). Despite these estimates, energy savings are dependent on a variety of factors, including type of crop, fertilizer, herbicide use, and the match between tractor, equipment and field size. Although no-till does save fuel, it may require greater expenses for fertilizer, seeds, and chemicals. Because farmers are primarily concerned with total production costs, the fuel savings feature of no-till may not be perceived as a major net advantage.

Equity Issues

A review of the research literature concerned with reduced tillage speaks almost exclusively of such issues as erosion control, crop yields, energy consumption, and herbicide/insecticide use. With few exceptions the social aspects of no-tillage agriculture have scarcely been investigated. Considering the relatively advanced state of current no-till adoption, as well as estimates for expanding the amount of land under no-till by 2000, the lack of social impact investigations of no-till on the sustained productivity of U.S. farmland is a significant gap in the nation's knowledge of this expanding technology.

Intergenerational Equity:

Soil erosion and soil compaction increase as tillage increases and as plant cover decreases. There is strong research evidence that no-tillage agriculture reduces erosion to practically zero where surface mulch of 2-4 tons per acre is used (Harrold, 1972). Other researchers have found that no-till reduces soil erosion by as much as 50-fold over conventional tillage (Phillips, Blevins et al., 1980). On slopes up to 15% no-till methods have reduced erosion to nearly zero. This would appear favorable to erosion reduction and sustained yield agriculture, but no-till could conceivably facilitate the cultivation of slopes or rangeland for which long-term cultivation is ill advised.

Although reducing soil erosion from wind and water is vital to sustained land productivity, reducing erosion also has implications for reducing pollution of water supplies. Farmers have been increasing the use of herbicides and insecticides for the past several decades. An estimated increase of 300 million pounds by the year 2000 will be required to be consistent with USDA projections for no-till increase (USDA, 1975). Because this increase in pesticides will occur largely on the 7 major annual crops, severe environmental problems could result. However, the adverse effects of pesticide pollution of water supplies is partially a function of the amount of run-off from treated acres. With the decline in water run-off and subsequent erosion, the transport of pollutants is reduced. Most of the persistent pesticides are strongly attached to soil particles so that a reduction in erosion will likely translate to a reduction in pesticide pollution of water supplies (Hahn, 1971).

There is a question of social exhaustion raised by multicropping under no-till, although research evidence is limited. It is reasonable to question whether, with enhanced capability for multicropping, there will be a tendency to neglect soil "resting" in favor of increased fertilizing. For example, soybeans are a typical second crop in the U.S., and their nutritive requirements are demanding of the soil. In 1969 nearly 2 million total acres were be double-cropped with almost all soybean production under a no-till system (USDA, 1975). In other words, a technology with broad potential intergenerational equity could, depending on national priorities, merely expedite monocultural agriculture and other soil-jeopardizing practices.

Temporal Equity:

Research to date implies that no-till methods are size-neutral, i.e., they do not benefit large farmers more than they benefit small. There is, though, room for speculation about the validity of such an assumption.

Whether a switch to no-till is financially attractive to a farmer is influenced by initial investment costs. For example, a new no-till planter costs slightly more than a conventional one. The decision to buy is partially related to credit available to small farmers and to whether the opportunity costs for labor are low. Part-time and small farmers' labor opportunity costs are generally lower and their access to credit more restricted than it for large farmers (Pereleman, 1977). Whether labor savings offered by no-till are sufficiently attractive to the small farmer to encourage a move into no-till are questionable. All other things being equal, larger farmers may find the labor savings attractive enough to off-set the costs of switching to no-till (Choi and Coughenour, 1979).

A change to no-till agriculture has other equity considerations significant to local farmers and farming communities. Although empirical support is tenuous, no-till adoption does raise questions about farm tenure changes and no-till's contribution to crop specialization and increases in farm size. In a recent single-county case study of Kentucky farmers who adopted no-till methods, early adopters of no-till had enlarged their farming operations over time--generally by renting additional lands (Choi and Coughenour, 1979). Smaller farmers tended to specialize in tobacco products and to use conventional tillage while larger operators incorporated no-till and specialized in cash-grain crops. Part-owner operators were more reluctant to give up tobacco raising than were full-owner operators, suggesting that the risks associated with changing to no-till and grain, at the same time foregoing the security of a tobacco income, were greater for part-owners than for full-owner operators (Choi and Coughenour, 1979).

The exact role of no-till in differential land ownership and use is ambiguous in the absence of further research. As with any new technology, no-till presents immediate farm management problems that qualify its contribution to social equity. No-till requires considerably more management expertise than conventional agriculture, including a greater knowledge of soil characteristics and a more detailed knowledge of the proper use of farm chemicals. No-till farmers must be more concerned than conventional farmers with selection of crop varieties, planting depth, seeding rates, and crop residue management. It is therefore arguable that competency in mastering no-till techniques was inversely related to educational level (Choi and Coughenour, 1979). Under these circumstances it is not surprising that smaller, often less educated operators are at a disadvantage in the use of no-till methods while larger, better educated operators have an advantage.

Public Policy

There has been no enabling legislation facilitating no-till adoption, though public policy exists which make it extremely relevant to intergenerational equity as here defined. The USDA spends several hundred million dollars annually on various soil conservation programs. The most promising piece of legislation for erosion control in some time is Section 208 of the Clean Water Act of 1972. While there are currently no mandatory controls on pollution, each state, under this legislation, is required to submit a plan to the Environmental Protection Agency for controlling pollution from all sources, including farmland.

As mentioned earlier, much ground and surface water pollution originates from non-point run-off from pesticide and fertilizer laden farmland. If voluntary efforts to reduce non-point pollution fail, regulations may eventually be imposed setting fertilizer and pesticide use restrictions.

In that event, no-till agriculture could offer one of the best ways of achieving erosion control while maintaining current productivity levels. It is also conceivable that the Congress could require sound erosion control measures as a condition for future farm subsidy programs administered by USDA.

Summary

Evidence is strong that, where adopted to currently cropped lands, no-till is a superior technology for reducing erosion and maintaining a high soil moisture level, thus controlling run-off and soil borne pollutants. There is some question whether the increased pesticide use often accompanying no-till methods has implications for altering soil quality over time. In addition, successive multicropping under no-till agriculture raises questions about the possibility of soil exhaustion and the overburdening of marginal lands. And, there is initial evidence that no-till may not be a size-neutral technology, contrary to popular belief. The proportionately greater risk associated with farm production failure may be less of a problem to the large farmer and, in the absence of public policies correcting information differences, relatively demanding farm management problems under no-till may also favor the larger, better educated operator with better access to extension and related services.

CASE STUDY FOUR: ORGANIC FARMING

Background and History

Organic farming, like no-till agriculture, is a whole system of agricultural productivity. As a system of production, and a system which stands as an explicit alternative to so-called conventional agriculture (Rodale, 1980a), it can have completely different implications for the inputs of production--machinery size and use, labor needs, soil and water use and retention, and fertilizer type and application, and the outputs of production--food quantity and quality.[11] In a recent study report on organic agriculture the U.S. Department of Agriculture defined organic farming as follows:

> Organic farming is a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes, mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests. (USDA, 1980:xii)

Modern organic farming originated with the work of Sir Albert Howard in England in the 1930s. Howard advocated greater attention to soil, the environment of growth, rather than the product of growth, the plant. For Howard, soil was capital which, if wasted, ceased to render crop dividends. Howard developed composting practices to replenish the soil and emphasized a holistic approach to food production, distribution, and consumption (Oelhaf, 1978).

Organic "technologies" thus concentrate on soil building, whereas conventional agricultural technologies focus on the end product, plant development. Organic farmers also tend to avoid monoculture production practices--the planting of a large amount of a single crop for successive years, as antithetical to successful soil building. In combination with mixed planting and crop rotation practices, this leads to long-term production security for the farmer. Among organic farmers this offsets any decrease in yearly income which may result from switching to organic farming methods[12, 13] (Oelhaf, 1978).

The current interest in organic farming (USDA, 1980: Rodale, 1980a) arises from the most obvious shortcomings of conventional farming: the decline in soil productivity due to erosion and sterility, the future availability of water for irrigation, the increasing costs and uncertain availability of energy and energy related products, and the cumulative effects of these three factors on environmental quality, human and animal health, and the general demise of the family farm (USDA, 1980; Crosson, 1979; Harris, 1980).

Characteristics

Empirical studies on the composition and structure of organic farming are few and very region specific. In terms of the total number of organic farmers, the USDA estimates that at most one percent of all American farms are organic (USDA, 1980). While there now is a registration system for organic farmers, it understates the adoption of organic technologies. In southern Minnesota in 1975 there were only 33 registered organic farmers; yet reliable estimates placed the actual number at closer to 300 (Oelhaf, 1978). Recently, Robert Rodale's organization did a survey of the 80,000 readers of _New Farm_ magazine. Results would suggest 11,000+ of the readers are complete organic farmers (though not all of these are full time farmers) and another 24,000+ are mixed organic and conventional farmers (Data Probe, 1980).

The size of organic farms is extremely variable. The USDA study found farms ranging in size from 10 to 1500 acres. A study in the Corn Belt matched organic and conventional farms for the purpose of comparing energy use. These farms averaged 429 acres in size and ranged from 175 to 844 acres (Klepper et al., 1977). Full time farmer respondents to the Rodale survey farmed on the average 200 acres, part time farmers less than 30 acres (Data Probe, 1980). Organic farms are regionally distributed throughout the U.S., though there seems to be fewer organic farms in the South (USDA, 1980).

Organic farming is much less energy-intensive than conventional farms. Klepper et al., in their study of Corn Belt farms, found that organic farms used 2.7 to 2.8 times less energy than conventional farms. This difference was highly correlated with reduced use of inorganic fertilizer, and the conservation farming methods of organic farmers[14] (Klepper et al., 1977). Studies on the labor-intensiveness of organic farming are mixed, but seem to indicate that organic farms are more labor intensive than conventional farms.

Organic farming is less capital-intensive than conventional farming. This is particularly related to the decreased use of petroleum based production inputs, such as fertilizers, and the decreased amount of land planted in row crops which then can require petroleum based field drying (USDA, 1980). This then leads to two other important characteristics of organic farming. They tend to carry a lower debt load than comparable conventional farms and, if the Rodale survey is representative of organic farmers in general, they own outright a higher proportion of the land they farm (USDA, 1980).

Finally, while the net crop yield per acre planted is roughly equivalent for organic and conventional farms, the total farm output is less in equal sized farms. The reason for this is that, as mentioned, organic farms plant less land to crops because of their mixed crop-rotation production practices. Consequently organic farmers' gross income is less than that of conventional farmers of similar size in the same region, though their net income may be equal because of the lower cost of production inputs (USDA, 1980).

Equity Issues

Intergenerational Equity:

Organic farming is a system of sustainable agriculture which retains the natural resource capital stock necessary for future food production. Organic farming practices build soil fertility, retard or eliminate soil erosion, conserve water, reduce or eliminate pollution and environmental health risks, and reduce use of non-renewable petroleum resources (Oelhaf, 1978; USDA, 1980).

Organic farmers generally implement those types of farming practices which the USDA has recommended for the last 50 years as a way to bountifully provide food while sustaining the food production resource.

Temporal Equity:

While organic farming exists on a wide variety of farm sizes, it is a system of production which can be said to be biased toward smaller production units. It is biased in that it can more easily allow for smaller farms to exist because of the need for less capital to get into and stay in organic farming [lower barrier to entry costs] (Oelhaf, 1978; USDA, 1980). Related to the size-neutrality of organic farming is its effects on land tenure. As noted, organic farming can be easier to get into and stay in because of decreased capital needs for petroleum based products which are ever rising in price (Loceretz, 1976). In addition, organic farmers are more stable because of their mixed planting practices, lower indebtedness levels and higher land ownership ratios (Oelhaf, 1978; USDA, 1980).

Organic farming is much healthier for the farmer, farm family, farm livestock, and area wildlife. Oelhaf notes that many organic farmers adopt organic methods specifically because of the adverse health impacts of conventional farming (Oelhaf citing Wernick and Lockeretz, 1977; National Rural Health Council, 1980). "Such farmers express a sense of relief that they can allow their children to wander freely about the farm again" (Oelhaf, 1978:147).

While evidence is inconclusive, a system of organic farming is likely to require more farm labor (USDA, 1980). Whether this would then translate into an economic and community multiplier is unclear. If it is assumed that a widely adopted organic system of agriculture would in fact be composed of smaller farms than the current system of production promotes, then studies such as those by agricultural economists Heady and Sonka and anthropologist Walter Goldschmidt suggested that a system of smaller farms would have significant local multipliers which would facilitate eocnomically stronger and socially more viable local communities and their attendant institutions (Heady and Sonka, 1974; Goldschmidt, 1946).

Oelhaf suggests that changes which encouraged organic farming would ultimately result in benefits for "the smaller, poorer, traditional, [and] poorly financed farmers" (Oelhaf, 1978:149).[15]

Public Policy

There is little direct federal, state or local public policy which regulates the actions of organic farmers. However, the USDA study found examples of current policy programs designed to support conventional agriculture which discriminate against organic producers. These examples include the local price support program administered by the Agricultural Stabilization and Conservation Service. It requires certain tillage practices, commercial fertilizer applications, and which does not count protected grasslands among lands eligible for price support. Also, USDA marketing orders are likely to discriminate against the cosmetic quality of organic food (USDA, 1980).

The availability of credit is another policy area in which organic producers are at a disadvantage. Generally financial institutions are reluctant to lend money for a farmer to convert to organic, though they willingly assist in a shift to conventional agriculture. Because of this, organic farmers, or even more so smaller ones, are likely to pay more for their capital needs. (Oelhaf, 1978; USDA, 1980; Pereleman, 1977). "For the most part those who have chosen to farm organically have done so in spite of financial incentives rather than because of them" (Oelhaf, 1978:146).

Summary

On a net yield per acre basis the quantitative output of organic farming is equivalent to that of conventional agriculture. Depending on the structure of an organic farming system,[16] the total output of crops and livestock produced by current U.S. agriculture can be equaled. Ecologically speaking, organic farming is effective for retaining the capital stock of production: soil, water and energy. Since organic farming does not require many of the petroleum based inputs of conventional farming, it is a less capital-intensive farming method. Because of lower debt levels comprised in part of higher land ownership ratios, organic farming is cheaper to get into and easier to stay in. Organic farming can facilitate stable smaller farms which have the potential for significantly contributing to local economic and social multipliers.

PUBLIC ATTITUDES

This discussion of public attitudes about the social equity/land productivity/technology relationship is organized around the distinction between intergenerational and temporal equity. It focuses on the attitudinal research of a limited number of issues, soil erosion and farm structure, both of which were important to the case study material.

Intergenerational Equity

Soil erosion and its converse, soil conservation, is a principal concept in the sustainability of land productivity and the achievement of intergenerational social equity. Soil erosion and soil conservation is a concept which has been examined for the public at large, local communities, and farmers. A recent Harris poll done for USDA as part of the Soil and Water Conservation Act of 1977 (PL 95-192), indicates a high level of support for intergenerational equity in resource use (Louis Harris and Associates, 1980).

This survey of 7-10 adult Americans indicates that the public prefers a country "that saves its resources to benefit future generations rather than using them to benefit the present generations" (60% favor; 24% oppose). Farmers in the survey take an even stronger pro-conservation position than the public at large. This same Louis Harris survey explored whether the American public prefers a country "that conserves the natural productivity of the soil rather than emphasizes chemical fertilizers and farm technology." Here, once again, 61% of respondents preferred such a country in contrast to 26% opposed. Farmers take a less decisive position to this question of chemical technology (44% versus 38%), though those identifying with natural productivity are in a majority.

The Harris survey also indicates that the public is well informed on soil issues. Of those in the sample, 50% consider the misuse of our soil and water resources a "very serious problem," while 53% consider the loss of good farmland to be a "very serious problem." With respect to public policy, the public sees soil conservation as an area of joint public and private responsibility, involving a partnership between the government and farmer. By a margin of 7 to 1, the survey respondants accept the propriety of the federal government to protect farmland from erosion. This propriety is tempered by the public's concern for an equitable relationship with farmers in which the government bears an appropriate portion of soil conservation costs.

Farm Size and Attitudes

The analysis of farmer attitudes toward soil conservation shows interesting differences between large and small farmers. A sociological survey in New York state indicated farm operators are generally "unalarmed about soil erosion" (Buttel, 1979:17). There is initial evidence, however, that small farmers are more supportive of soil conservation efforts than larger farmers. In the New York survey, small farmers showed a higher level of concern with problems of soil erosion and a greater propensity to take action to solve soil erosion problems than did larger farmers (Buttel, 1979). Kasal (1970) found a similar response pattern between small and large farmers in examining operator attitudes toward the Great Plains Conservation Program. Kasal surveyed conservation program participants and non-participants in eastern Colorado and Kansas and found that small farmers in both groups tended to approve of the program more than large farmers. These results are interesting in that small farmers tend to be less financially able to make such investments.

In 1978 and 1979, the "Heartland Project" of the Catholic Church conducted some 400 meetings with local residents in 12 north central states on matters of land use, farming practices, and sustainable rural lifestyles. With respect to mechanization effects, variously defined, the Heartland inquiry pointed repeatedly to a similar dichotomy between small-to-medium scale and large scale farm operators. The latter were prone to speak in support of technology, stressing cost reductions from time and labor saved and noting the benefits of technological adaptability when weather conditions would otherwise have precluded planting or harvesting. Small and medium sized farmers selected other aspects of technology for discussion such as compacted soils, rising energy costs, and trends towards reduced tenure security as they increasingly rented land for their farm operations.[17]

Absenteeism and Conservation Adoption

A survey in the state of Washington illuminates a growing controversy: does absenteeism correlate with inferior soil conservation practices. There, researchers investigated the anti-erosion activities of non-resident owners and determined, contrary to what many believe is the normal behavior, that such owners were conscientious about conservation practices. Close inspection of those surveyed, however, indicates that many of those identified as "absentee" farmers were the widows of previous farmers who frequently maintained close community and farm ties subsequent to moving away from the farm as a place to live (Dillman, 1978).

Temporal Equity

The four cases presented above stress the importance of farm size and operator ownership in establishing temporal equity effects. The Harris/USDA 1980 Survey indicates public approval for the concept of the small family farm and federal policies aimed at preserving and increasing the number of small family farms in the United States. Specifically, 60% of respondents felt that we should be moving toward a country which has a relatively large number of small farms, while just 19% feel we should be moving toward a country which has a relatively small number of large farms (Louis Harris and Associates, 1980). Furthermore, the same source reports that 67% of the public supports new federal controls on farmland ownership to increase the number of small farmers in the country. Farm owners and managers together adopt a similar position 62% of the time. Another national survey (Response Analysis Corp., 1974) shows even stronger support for small farm structure. In this sample, 94% favored preserving family farms, and 90% agreed with the statement that, "It is important to preserve and encourage family farms."

Diffusion of Innovation Research

One of the most instructive bodies of literature illuminating the temporal equity effects of assorted technologies in agriculture is found in the vast literature on technological diffusion. Rogers and Schoemaker (1971) cite hundreds of articles on the topic of diffusion, many of the classic cases being in agriculture. Typically, these studies examine characteristics of technology adopters (e.g., levels of education, entrepreneurialism, media exposure, or need for personal achievement). The efficiency oriented technology adopter is assumed to act rationally insofar as technology adoption fosters production gains which translate into profits. Alternatively, critiques of the productivity-prone model identify structures (credit barriers, racial barriers, class barriers, agribusiness barriers) which, like the structure of U.S. agriculture more generally, exert non-size neutral obstacles upon small farmers and keep them at comparative disadvantage regardless of education and other personal characteristics.[18]

Summary

This brief section touches on only two aspects of public attitudes: soil erosion (intergenerational equity) and farm size/structure (temporal equity). The literature cited here, although not exhaustive,[19] suggests the importance of soil conservation (sustainable productivity) and a viable small farm structure as public policy priorities among the American public.

SOCIAL IMPACT ANALYSIS

This section discusses the current state of social impact analysis from several standpoints: how well established are such methodologies where agricultural technologies are at issue; what is the state-of-the-art in formal (NEPA-mandated) SIA as a tool of applied, scientific research; is social equity analysis within the scope of current SIA theory and methods; and, finally, is there non-NEPA social impact research bearing on the future direction of agricultural SIAs? The section will provide a brief history of SIA, a critique of SIA cost-benefit orientation in light of other purposes to which SIA is put, and suggestions for a social equity basis for SIA.

Social impact analysis, with few exceptions, has generally shown a lack of scientific rigor, a narrowly conceived cost effectiveness bias acquired from conventional economics, and, most importantly, a persistent unwillingness to deal explicitly with social equity concerns. Moreover, a rigid emphasis in SIA upon checklists of easily quantified items or impact areas has become an institutionalized barrier to SIA innovation.

SIA, as an evaluative tool for public policy and planning, is a rather recent development dating to perhaps the early 1970s.[20] Its analytic focus is one of "estimating and appraising the conditions of a society organized and changed by large scale applications of high technology" (Wolf, 1977:3)

History

Concern with unanticipated social effects of industrial, agricultural and technological development is not a new research focus (Scatterfield, 1937; Cottrell, 1951; Hypes, 1944; Hamilton, 1939). Since passage of the National Environmental Policy Act (P.L. 91-190), the evaluation of social impacts has had a legal basis in those areas where projects and programs use government funding. This legal support for SIA requires formal social analyses as part of the environmental impact statement mandated under that legislation and underscores the increasing importance assigned to understanding the secondary impacts of new policies and practices.

Because agriculture provides society with such basic necessities, it is reasonable to expect that publicly sponsored innovations therein would receive continuous SIA scrutiny. Not only is this not the case, however, but the state-of-the-art in SIA is generally unsatisfactory from several standpoints. At times scientific rigor, including the use of models and estimating equations, seems artificially imposed (Flynn, 1976). At others, conscientious social science analysis is absent or strictly token. Wilke and Caine (1977) determined, in a random sample of 80 environmental impact statements, that:

> Social research methods or techniques could be found in only 13.5% of the cases; a logical, explicit, social relationship could be found in only 11% of the cases; and planning for long term impacts was present in only 21.3% of the EISs (environmental impact statements).

In part these problems stem from cumulative inattention to theoretical and methodological problems which all SIA researchers share, as well as from the formidable constraints under which most SIAs are conducted. And, in part, they stem from the politics and vested interests surrounding research priorities. Even if greater SIA efforts were available with respect to technology innovations in agriculture, for instance, they would have to contend with long-standing biases against small farm operations held by many officials and decision makers in USDA, in land grant colleges and universities, in Agricultural Experiment Stations, and elsewhere.[21] Said another way, the structure of U.S. agriculture and the influence this structure exerts on public sector definitions of what is functional, efficient, and rational for agriculture are likely to deflect standard SIA research from the social equity issues raised in the present report. If such biases take effect, agricultural SIA will be no more size neutral than the technologies it might be assigned to evaluate.

Method and Practice of SIA

Cost-benefit analysis, acquired from economics, has become the routinized methodology among many SIAs. Mishan (1976;382) defines cost-benefit analysis as "the study which endeavors to formulate propositions by which we may rank on the scale of better or worse, alternative economic situations open to society." In the final analysis, only costs and benefits which can enter the marketplace and be assigned economic values--that is, quantified--receive serious attention. Whereas cost-benefit analysis serves useful analytic purposes,[22] it must by definition discount future benefits to society. Sustained yield agricultural systems which provide for future generations assume comparatively little importance in an evaluating system predicated on present monetary values. The intangibility of future agriculture security biases cost-benefit analysis, and SIA dependent on it, against a redefinition of productivity.

This emphasis on quantifying present value has, in the majority of cases, limited the substance of SIA to elaborate checklists of measureable items which in turn can be arbitrarily assigned numerical values and subjected to mathematical models. The value of community cohesion, the multidimensional significance of land ownership, or the deprivations of being a migrant displaced by a tomato picker resist easy quantification and are easily omitted from such checklist efforts. Thus, it is too often the case that SIAs are measuring indicators quite reliably that contribute very little toward understanding comprehensive social impacts which resist easy categorization.

Productivity-as-efficiency biases, of course, exist more generally in Department of Agriculture research assumptions, and will be slow in changing. According to the Pound Committee, empaneled to examine research within USDA, social science research therein and in state agricultural experiment stations was 90% economics and 10% sociology in 1973. Out of a total 539 scientific-man-years devoted to the social sciences by USDA, 18 were in sociology. This token interest in social variables, and therefore social consequences of new policies and technologies in agriculture, was noted by the Pound Commission and has subsequently been questioned by the Secretary of Agriculture himself. "Until recently," commented Secretary Bergland (1980), "agricultural research was evaluated almost exclusively in terms of what that research promised in the way of volume productivity gains. Too often potentially negative economic and social effects were not factored into the evaluation."

SIA, Equity, and Agriculture

Equity is a relevant but severely neglected dimension in SIA, especially so in the SIAs conducted under NEPA. Although it is not unreasonable to suggest that questions of social equity, explicitly or implicitly, motivated research into the social effects of technology, those questions have rarely been asked systematically or researched. Besides offering a different perspective from which to understand the social consequences of agriculture mechanization, social equity also suggests important theoretical ties to a range of disciplines. Several theoretic rationales and sociolocial studies indicate possible directions that SIA could take with respect to assessing the social impacts of agricultural technologies and at the same time moving SIA practice beyond the confines of cost-benefit calculus.

Human ecology (e.g., Hawley, 1944; Cohen, 1976) is a subfield within the social sciences with potential relevance to SIA and equity analysis as here defined. Firey (1960) analyzes the adoption of irrigation technology abroad from this perspective, and Duncan (1958) sensitizes his colleagues to the important interrelationships between such variables as population, technology, the environment and social organization. Others have treated energy as a sociological variable (Cottrell, 1955), have argued for greater use of systems theory in social science research (Bedford, 1968; Boulding, 1980), and have explored important social consequences of natural resource exhaustion (Schnaiburg, 1975).

In 1946, anthropologist Walter Goldschmidt prepared detailed case studies of communities in central California matched by size, geographic features, and agricultural base. The distinguishing feature of these two communities was the ownership and control of farm units. One was dominated by absentee farm corporations which had not divested excess lands as required under the Reclamation Law of 1902. The other consisted of smaller family farms. The latter supported a greater number and variety of businesses, churches, schools, facilities and viable institutions, a finding Goldschmidt (1978) and others have used to suggest that moderate farm size and non-absentee ownership are critical elements in attaining local social equity.

The Goldschmidt study is important here because of his careful use of community case studies to isolate the effects of important features of rural community structure, farm size and ownership. This use of community analysis permits a close-up view of the complexity of social and economic forces at work in agricultural production.

In contrast to Goldschmidt's community case study approach, Heady and Sonka (1974) use a national linear programming model to evaluate the effect of different patterns of farm size on the welfare of rural communities. The study provides insights into economic tradeoffs among consumers, large farmers, small farmers and the rural community. It is important in that it provides a framework for directly including community impacts in the evaluation of agricultural production systems and can be replicated in the analysis of potential social impacts of agricultural technology with a farm-size bias.

Social impact assessment is intended to be anticipatory research. Friedland et al. (1978) make a significant contribution toward this end in their development of "social projection" analysis. They begin with a recognition that agriculture is an industry, and, like other industries, its production processes are closely tied to the technologies it uses. This framework permits technology to be considered as a variable (as opposed to a constant without alternatives), permitting alternative technical systems to be evaluated with respect to their social impacts. Friedland and associates have used "social projection" to thus evaluate alternative technical changes in lettuce production, thus establishing a model for other agricultural cases.

Potentially Useful Non-Agricultural SIAs

Two related bodies of SIA literature also suggest the importance of social equity considerations: studies of boomtowns and of rural industrialization (Gilmore and Duff, 1975; Gold, 1974; Cortese and Jones, 1977; Summers, Clemente et al., 1976; Smith, 1971). The former deal with the social effects that rapid energy development has brought to small, remote communities in the western U.S. Rapid, unmanageable change stemming from sudden population increase has brought a host of undesirable impacts including housing shortages, conflicts between new residents and natives, and dramatic increases in alcoholism, divorce, and other mental health problems.

Industrial location in rural areas has prompted sociological research into the way different impacts affect different groups at different times (Spangler, 1974; Bonnen, 1970; Schnaiberg and Meidinger, 1978). Research on rural industrialization has demonstrated that benefits are disproportionately distributed by age, sex, race, and education. For example, industrial siting decisions suggest that farmers and prime agricultural land are often vulnerable to change which they can neither control nor anticipate.

Studies of boom towns and rural industrial communities have focused on the community as the unit of analysis. Regardless of whether the source of change is a new industrial complex, mineral extraction, or agricultural technology the processes of community change may be quite related. Roland Warren (1972:53-4) has termed this process the "great change" in community organization:

> ...[T]he "great change" in community living includes the increasing orientation of local community units toward extra-community systems

> of which they are a part, with a corresponding decline in community cohesion and autonomy. As the relation of community units to state and national systems becomes strengthened, the locus of decision-making with regard to them often shifts to places outside the community.

Warren (1972) analyzes local and non-local community linkages in terms of "horizontal" and "vertical" patterns of community organization. Horizontal linkages are the relations of a community's social units to each other, and comprise the social fabric observed by Goldschmidt in smaller farm communities. Vertical linkages are the relations to non-local or extra-community systems, for example, international markets, credit sources, or business centers. Warren argues that the trend is toward increasing ties along the vertical axis with a subsequent decline in the horizontal ties. The former tends to be more rational, planned, and bureaucratically structured than horizontal ties.

Agriculture, because of its increasingly planned, rational, bureaucratic structure, may be regarded as a rural industry with important influence over a community's social relations, i.e., its relative position on a vertical/ horizontal plane. Thus, local farming communities supporting center pivot irrigation or mechanized tobacco and cotton operations, rural industrial communities, and boomtowns are part of a larger class of theoretically similar types (Shields, Cowan & Bjornstad, 1979). All are characterized by general processes of social change that are, in part, created by large scale technology with implications for horizontal community ties as well as social equity.

Summary

SIA is conceptually promising for anticipating the consequences of technological innovation. In practice, however, it has been disappointing. Existing theory and methods within the social sciences have not been incorporated into most SIAs. Their inclusion would balance the efficiency bias of cost-benefit analysis with social equity concerns, providing SIA with a useful theoretical foundation.

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

Our purpose has been to examine the social consequences and equity implications of agricultural technology as they pertain to sustained land productivity. The results of this examination are contingent upon the definition of productivity used. The prevailing view of agricultural productivity or rangeland productivity draws attention exclusively to efficiency and returns on investment. Social consequences are accorded secondary consideration, as are those of the biological community upon which human communities depend. In the present review, productivity is construed as long-term system sustainability, wherein both present and future yields are of equal concern.

The centerpieces of sustainable agriculture are our "capital stock" of soil and water. This societal capital is being drawn down under present technology applications to agriculture, due largely to the efficiency bias cited. As a consequence, the renewability of our agricultural system from one generation to the next can no longer be taken for granted. Given the redefinition of productivity as sustainability, soil and water protection becomes a social indicator with important implications for future social impact assessment of agricultural technologies.

Agriculture is a socio-technical system of production and technological changes occur within this context. It is this socio-technical structure that preserves the efficiency orientation of conventional production and which selects technologies which favor large scale producers. Acceptance of sustainability-oriented technologies presupposes contextual changes in the structure of agriculture, changes likely only with public sector direction.

Conclusions

In this section a set of conclusions is presented which emphasizes (1) the key factors behind the equity/productivity/technology relationship, (2) the usefulness of SIA for evaluating the relationship, and (3) relevant public attitudes/survey research:

American agriculture is decreasingly productive in its present form, given a broader definition of productivity which encompasses present and future social equity. We are abandoning sustained yield agriculture for short-term productivity gains and resolution of trade pressure. Concurrently, public opinion shows support for soil conservation (sustainable agriculture), and for small farm redevelopment.

The spread or increased use of capital-intensive agricultural technology (CIT) is likely to have adverse social equity impacts at the local level. CIT tends to favor large farm units and deplete or diminish basic human and natural resources. Thus, while CIT may increase current benefits , it generally does so at the cost of temporal and intergenerational equity. Non-CITs, like organic farming, are competitive with CIT on a current productivity basis while simultaneously improving social equity for small farmers and rural communities. The alledged tradeoff between "productivity and equity" would therefore appear to be a false dichotomy.

The size neutrality (lack of farm size bias) of emergent technologies is ambiguous and such technologies can be subject to the "current yield" productivity bias of CITs. To the extent that emergent technologies foster small farm and small community viability, they are more equitable.

There is genuine need for an unbiased approach to SIA of agricultural technology. Traditional SIA overvalues current benefits and discounts those of the future and therefore sustained yield agriculture. The cost-benefit framework of traditional SIA is inadequate for conducting social equity analysis. A body of social impact/evaluative studies exist which is not bound by the narrow cost-benefit approach of accepted SIAs. This alternative work begins to address important social equity issues and provides direction for future SIA of agricultural technology.

With few exceptions, current public policies tend to support CIT, overemphasizing current productivity yields to the detriment of agricultural sustainability. This bias will discriminate against technology which fosters small farm and community viability. Currently, there is a critical lack of public policy for monitoring, anticipating, and making restitution for the real and potential social consequences of agricultural technology.

Recommendations

Following from the preceding conclusions on the social equity of technological changes that affect land productivity, the authors offer recommendations for further policy research and action:

One. Research should be undertaken to investigate more fully the theoretical and methodological implications of using social equity concepts in social impact assessments, especially those in agriculture. Our overview supports the potential utility of the social equity concept in SIA. The concept takes into consideration explicit concerns for the physical and social spheres and the future and present time periods. Further research is needed on the assessment of agricultural technologies, such as those used as cases in this report, from a perspective which contrasts local/regional social equity with national and international social equity.

Two. SIAs should be prepared, preferably under NEPA and using the social equity concept, on programmatic agricultural research in the U.S. A recent research project conducted at the University of Nebraska Law School suggests that such anticipatory evaluations might have helped in understanding the likely impact of center-pivot irrigation on Nebraska localities. Such SIAs should consider multiple technological alternatives, as opposed to assessing the likely impacts of a single option.

Three. Evaluative research should be conducted on past public programs which granted compensation, resettlement, or other considerations in the wake of technological innovations.

Four. Survey research should be conducted which explores the relationships between social equity, technology and land productivity. Existing opinion data in related areas should be carefully reviewed for its relevance to these concerns and new research should be undertaken to illuminate public attitudes and perceptions toward the social consequence of technological innovations that impact land productivity.

Five. The Office of Technology Assessment, or other federal agencies, is encouraged to hold workshops around the issues raised in this report -- the shortcomings of existing SIA theory and methodology, the potential utility of the social equity concept in the SIA process, and more generally the social consequence of technological innovations that impact land productivity. Meetings which brought together the general public with professionals, academics and SIA practitioners would provide a wealth of information, insight and needed public feedback on this topic of national interest.

FOOTNOTES

1. For small producers this access to capital problem is compounded by higher interest rates charged by financial institutions, and lower discount rates offered by supply houses (Pereleman, 1977).

2. Though the far west, lacking the plantation system of the southeast, mechanized its cotton harvests sooner, the labor displacing effects of this automation were dramatically similar to the southeast (Elliot, 1962; Barnett et al., 1978).

3. The hazards of cotton and tobacco production to soil fertility and loss prior to mechanication are well documented (e.g., Craven, 1926; Shastry, 1948; Street, 1967; Genovese, 1967; Trimble, 1974). Consequently southeastern cotton soils were subjected to heavy fertilizer applications early in the century (Baker, 1926).

4. No longer were planters subject to the vagaries of the commodity market (acreage allotments were insurance against radical price fluctuations) or of an increasingly mobil and migratory labor market (Mydral, 1941; Tindall, 1967; Ford, 1973). Planters could now absolve themselves of contractual responsibilities to tenants and sharecroppers and could channel profits into additional land (thus increasing their allotments) and crop diversification such as corn, soy beans and small grins (Fulmer, 1950; Day, 1967).

5. See, for example, Nesbitt (1979). Marable (1979) reviews the substantial efforts by black agricultural and teachers' training colleges in the South to further black ownership and citizenship. Holly (1975) evaluates the after-effects of federal Resettlement Administration relocation and ownership programs in Arkansas, Louisiana and Mississippi. Raper (1936) makes explicit how limited ownership was functional for plantation production prior to the 1930s, just as limited proprietorship threatened this system at its base.

6. The Subcommittee on Technology (cited above) foresaw in 1937 that up to three-quarters of tye 8-9 million tenants in southern cotton fields might become occupationally redundant if "mechanization proceeded rapidly without substantial change in the present cotton acreage" (Horne, 1937: 142). It was this same Subcommittee that drew attention to the secondary impacts on wage levels, organized labor and standards of living elsewhere.

7. According to the "agricultural ladder" of occupational statuses, wage labor traditionally implied a status below that of sharecropping and tenancy (Marable, 1979), probably due to its inferior incomes (James, 1980).

8. These reasons were both direct and indirect. The AAA insisted that the benefits of acreage allotments be equally shared between planter and employees, including sharecroppers. Sharecroppers were consequently displaced en masse to reduce claims on cotton profits (Musoke, 1976). Though it was widely accepted throughout the South that cotton production could be mechanized but for the harvest (Street, 1967), there was now ample incentive to substitute machinery as tenants and sharecroppers were

released. Just as important, other commercial crops now produced on southern plantations were mechanized, meaning that larger landowners already had substantial investments in tractors which remained idle or under-utilized when the cotton harvest occurred (Martin, 1972; James, 1980).

9. Attempts were made to market a small-scale cotton harvester affordable by small producers before and after the 1930s, but were frustrated (especially in the latter case) as the overall scale of production outpaced families of limited means (Street, 1957).

10. Acceptance and adoption of no-till practices has had regional variation. In the southern half of the eastern Corn Belt no-till has been well received; but, in part, because of differences in soil types, adoption of no-till in the northern half has been less widespread. Indeed, soil type and in particular, drainage, is an important consideration in the degree to which no-till practices can be employed. Research has indicated that poorly drained soils are less suited to no-till than are those that do drain well (Phillips and Young, 1973).

11. In one of the principle scholarly works on organic farming, economist Robert Oelhaf identifies four distinct sub-groups to the organic agriculture movement: organic farming, bio-dynamic agriculture, French intensive farming and eco-agriculture. All are organic in that they emphasize (1) the building of soil over the direct feeding of plants, (2) the general rejection of pesticides, and (3) the importance of measuring productivity in terms of food quantity and quality. The rejection of pesticides by organic farmers has to do not only with their inorganic nature but, even more importantly, with pesticides emphasis on plant growth over soil building (Oelhaf, 1978).

12. In studies of farmers' attitudes toward production, farmers are often found to place high value on the avoidance of risk. At the same time, farmers also want to be independent proprietors. However, the importance of the former value over the latter often leads them to enter into contractual arrangements--so-called vertical integration of the production process with food suppliers--which can greatly decrease their independence (Oelhaf, 1978; Davis, 1980).

13. Most full time organic farmers in the U.S. have had substantial previous experience as chemical/conventional farmers (USDA, 1980).

14. Conservation farming methods refers, in part, to the use of terracing, contour plowing, a fallow or green manure system of crop rotation which decreases the total amount of land planted to crops and a mixed crop pattern of planting which decreases the amount of cropland given over to row crops, which, while of high short-term value, deplete soil productivity and tilth.

15. This is not to suggest that an organic system of production is without its problems. At present a wholesale shift into organic agriculture is impossible in the U.S. due to lack of sufficient organic wastes and lack of labor. Even if possible, it would be difficult because a shift from conventional to organic farming methods requires a three to four year transition period during which time there are significant

decreases in total yields and hence on-farm income; also the current technical support structure for conventional agriculture which provides substantial public investment in university agriculture extension, research and teaching programs, does not exist for organic farming (USDA, 1980).

In addition, it should be noted that an organic system of production may result in increases in food prices. Also it has been suggested that an organic system in the U.S. may shift temporal and intergenerational equity burdens onto populations in less developed countries. If the U.S. shifted to organic production, and if total production yields dropped, LDCs which now import U.S. crop surpluses may seek to boost in-country production through use of capital-intensive fertilizers, pesticides and mechanization. While these actions might offset import drops they are also likely to hasten soil erosion and sterility (Oelhaf, 1978).

16. A 1979 Gallup survey on home gardening found that the vegetables produced in home gardens are one-third of the total retail value of all produce grown in the U.S. (Gallup, 1979). Robert Rodale suggests that home gardens yield two to four times more crop per unit area than current commercial yields (Rodale, 1980). These two items suggest that organic production systems which include explicit designs for encouraging home production could equal the total output of conventional agriculture.

17. Personal communication with Heartland Project Director, Dr. John Hart, by phone (5 November 1980).

18. Literature critical of the standard diffusion model appears in review of Green Revolution innovations abroad (in its first generation, the Green Revolution mirrored with great fidelity the productivity-as-efficiency perspective of the United States) (e.g., Aiken et al., 1974). It can also be found among sociologists trying to account for why local residents periodically resist flood control measures proposed by the Corps of Engineers and TVA--two organizations widely reputed for their cost-benefit approaches in making public works decisions with far-reaching social overtones (Johnson, 1974).

19. Other important attitudinal studies exist which bear on equity. Of prominence are the attitudes of farm workers toward mechanization (see Thomas, 1980; Barton, 1977) and pesticide use/health effects (National Rural Health Council, 1980).

    One such study is currently on-going at Cornell University ("The Small Farm Decision-Making Project") and has interviewed 21 upstate New York farm families every year since 1967. A much earlier example occurred at Iowa State College ("Some Social Factors Associated with Land Utilization in Southern Iowa"). It studied the movements of farm families in about 25 townships in 15 Iowa counties in the interest of better understanding the relationships between soil erosion, mobility and land tenure (Wakeley, 1936).

20. Technology assessment, a term often used in association, or interchangeably, with SIA, is concerned with judgements in accord with a technology's purpose (Shrader-Frechette, 1980). A useful analytic distinction between

SIA and technology assessment is that technology provides causal influences which may express themselves in social impacts (Wolf, 1977).

21. There are of course exceptions to this norm worthy of mention. In January, Secretary Bergland took what many view as an exceptional stand in publically commenting, "I find it difficult if not impossible to justify the use of federal funds to finance research leading to the development and processing of machines or other technologies that may increase production and processing efficiency but at the same time damage the soil, pollute the environment, displace willing workers, and reduce or eliminate competition" (Bergland, 1980). See also the recently released "Evaluation of Economic and Social Consequences of Cooperative Extension Programs" (USDA, 1980), and the response of Experiment Station Directors in Day (1980).

22. When a goal is clear, agreed upon, and when the nature of benefits and costs are well understood, cost-benefit is a valuable tool for choosing alternatives for arriving at the end point (Nelson, 1976).

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SOCIO-ECONOMIC CONSEQUENCES OF MECHANIZATION

(INDIRECT AND DIRECT)*

Supplement to Citations in

"Socio-economic Consequences of Agricultural Mechanization in the United States:
Needed Redirections for Mechanization Research"

CONSEQUENCE	CITATION(S)
(Effects of Mechanization on Numbers and Characteristics of the Farm Work Force and Farms)	
decrease in the farm work force	Quaintance, 1904; Bonnen and Magee, 1938; Hamilton, 1939; Drucker, 1946; Raper, 1946; McMillan, 1949; Bertrand, 1951; Motheral, 1953; Cottrell, 1955; Loftsgard and Voelker, 1963; Kendrick, 1964; Metzler, 1964; Bagdikian, 1967; Tolley and Farmer, 1967; Rasmussen, 1968; Davis, 1969; Fulco, 1969; Uhl, 1969; Vincent, 1969; Fusfield, 1970; Hennessey, 1970; National Planning Association, 1970; Schmitz and Seckler, 1970; Ponder, 1971; Woolf, 1971; Friedland and Nelkin, 1972; Guither, 1972; Lianos and Paris, 1972; Perelman, 1972; 1976; Black Economic Research Center, 1973; Donaldson and McInerney, 1973; Heady, 1974; Miller, 1975; Perelman, 1977; Rasmussen, 1977; Martin and Johnson, 1978
expansion of plantation system and use of slave labor	Genovese, 1965; Rasmussen, 1977; Hambidge, 1940; 1978
decrease in number of black farmers	Raper, 1946; Pederson, 1952; Hamilton, 1964; Vandiver, 1966; Bagdikian, 1967; Ponder, 1971; Black Economic Research Center, 1973; Rasmussen, 1977

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*NB: Many of these articles do not provide empirical evidence sufficient to prove causality.

Source: G.M. Berardi, "Socio-Economic Consequences of Agricultural Mechanization in the United States: Needed Redirections for Mechanization Research." Unpublished manuscript available from author, Dept. of Geography, University of Maryland—Baltimore County, Baltimore, Maryland 21228

CONSEQUENCE	CITATION(S)
adjustment - least educated and skilled workers	Quaintance, 1904; Hamilton, 1939; Raper, 1946; Mellor, 1954; Lianos and Paris, 1972; Rasmussen, 1977; Martin and Johnson, 1978
transition most difficult for minorities	Dillingham and Sly, 1966; Bryant and Leung, 1967
- especially due to discrimination	Pederson, 1954; Hamilton, 1964; Dillingham and Sly, 1966; Bagdikian, 1967; Ponder, 1971; Black Economic Research Center, 1973
more free time	Quaintance, 1904; Bertrand, 1951
less "drudgery"	Quaintance, 1904; Bertrand, 1951; Street, 1957; Carleton and Vanden Berg, 1970; Donaldson and McInerney, 1973; Rodefeld, 1974; Rasmussen, 1977
increase in dangers to health and safety	Donaldson and McInerney, 1973
increased sales per farm	Bonnen and Magee, 1938; Raper, 1946; McMillan, 1949; Bertrand, 1951; Bertrand *et al*., 1956; Heady, 1960; Rasmussen, 1962; Tweeten, 1965; Constandse *et al*., 1968; Woolf, 1971; Hatch, 1975; Rodefeld, 1975
increase in standard of living	Bonnen and Magee, 1938; Raper, 1946; McMillan, 1949; Bertrand, 1951; Street, 1957
shift in values, life styles	Bertrand, 1951; Donaldson and McInerney, 1973
shift in age of farm operators	McMillan, 1949
increase in women in the farm work force	Quaintance, 1904; Friedland and Barton, 1976
decrease in use of child labor	Raper, 1946; Street, 1957

CONSEQUENCE	CITATION(S)
change in occupational composition	Rodefeld, 1974; 1979
decrease in number of farms	McMillan, 1949; Brewster, 1958; Loftsgard and Voelker, 1963; Guither, 1972; Donaldson and McInerney, 1973; Rodefeld, 1974; Gardner and Pope, 1978
increase in size of farms	Taylor, 1938; Saville, 1941; Raper, 1946; McMillan, 1949; Parsons and Owens, 1951; Bertrand *et al.*, 1956; Loftsgard and Voelker, 1963; Shea, 1966; Field and Dimit, 1970; Krause and Kyle, 1970; Ball and Heady, 1972; Kyle *et al.*, 1972; Perelman, 1972; Donaldson and McInerney, 1973; Rodefeld, 1974
productive assets - concentrated on largest-sized farms	McMillan, 1949; Krause and Kyle, 1970; Ball and Heady, 1972; Breimyer and Barr, 1972
difficult to enter farming	Quaintance, 1904; Gates, 1960; Field and Dimit, 1970; Perelman, 1972; Donaldson and McInerney, 1973; Rasmussen, 1977
- especially for minorities	Raper, 1946; Ponder, 1971; Black Economic Research Center, 1973
increase in labor productivity	Pederson, 1954; Kenderick, 1964
increase in timeliness of field operations	Quaintance, 1904; Carleton and Vanden Berg, 1970; Donaldson and McInerney, 1973; Hatch, 1975; Perelman, 1977
decrease in hillside farming	Raper, 1946
specialization of enterprises	McMillan, 1949; Bertrand, 1951; Field and Dimit, 1970; White and Irvin, 1972

CONSEQUENCE	CITATION(S)
more industrial/commercial character to agriculture	McMillan, 1949; Donaldson and McInerney, 1973
interdependence with nonfarm sector	Quaintance, 1904; Hamilton, 1939; McConnell, 1953; Gates, 1960; Donaldson and McInerney, 1973; Perelman, 1977; Rasmussen, 1977
(Effects of Mechanization on Rural Society)	
migration out of rural areas	Quaintance, 1904; Bonnen and Magee, 1938; Hamilton, 1939; McMillan, 1949; Chittick, 1955; Anderson, 1961; Beegle, 1961; Hill, 1962; Guither, 1963; Loftsgard and Voelker, 1963; Kendrick, 1964; Bagdikian, 1967; Field and Dimit, 1970; Hennessey, 1970; Reeder and LeRay, 1970; Perelman, 1972; Black Economic Research Center, 1973; Donaldson and McInerney, 1973; Flora and Rodefeld, 1978
loss of community functions	Raper, 1946; Anderson and Miller, 1953; Chittick, 1955; Fuguitt and Deeley, 1966; Brunn, 1968; Folse and Riffe, 1969; Field and Dimit, 1970; Hightower, 1972; Donaldson and McInerney, 1973; Heady, 1974; Rasmussen, 1977; Raup, 1978
churches and schools closed	Bertrand, 1958; Kolb, 1959
political power base eroded	Donaldson and McInerney, 1973
decrease in child labor	Raper, 1946; Bertrand, 1951; Street, 1957
soil compaction	Perelman, 1972; Pimentel, 1976
increased use of fuels	Cottell, 1955; Perelman, 1972; 1973; Pimentel et al., 1973; 1974; 1975; Carter and Youde, 1974; Clark, 1975; Berardi, 1977; 1978; 1979

CONSEQUENCE	CITATIONS(S)
(Effects of Mechanization on Urban Society)	
increased racial tension	Vandiver, 1966; President's National Advisory Commission on Rural Poverty, 1967; Fujimoto, 1969; Hennessey, 1970; Hightower, 1972
lack of variety - food supply	Consumer Reports, 1973; Robbins, 1974
lowered quality - food supply	Quaintance, 1904; Hightower, 1972; Perelman, 1978
increased cost - food supply	Robbins, 1974; Consumer Reports, 1975; Hightower, 1975
increased variety - food supply	Lorenzen and Hanna, 1962; Lorenzen and Fridley, 1966; Rasmussen, 1975

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Background Paper No. 13

MULTIPLE CROPPING SYSTEMS: A BASIS FOR DEVELOPING AN ALTERNATIVE AGRICULTURE

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Office of Technology Assessment
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ABSTRACT

A general discussion of the concept of Multiple Cropping is presented, including a description of the different types of systems, and the advantages and disadvantages of their widespread use, both biologically and socioeconomically. These systems are designed to achieve the intensification of agricultural production not only in terms of yields per unit area, butalso through the more efficient use of space and time.

Examples of yield increases with Multiple Cropping systems are expressed in terms of Relative Yield Totals (RYT) or Land Equivalent Use (LER) where the production per unit area with the multiple cropped field is greater than the sum of equivalent areas planted to the monocultures. This increase in production is explained in terms of higher over-all efficiency of resource use.

Specific cases of the effects of multiple cropping systems on resource use, conservation,and management are discussed: microclimate, light, soil, water, pests, diseases, weeds, crop interactions, and space and time. The special case for Agroforestry as a multiple cropping system is discussed in more detail for the combinations of trees with crops and grasses.

In conclusion, the socio-economic implications, both advantageous and disadvantageous, are discussed, considering that the perspectives for multiple cropping systems in agriculture in the United States show great potential. Research needs to be oriented towards testing these alternatives.

Background Paper No. 13

MULTIPLE CROPPING SYSTEMS: A BASIS FOR DEVELOPING AN ALTERNATIVE AGRICULTURE

By: Dr. Stephen R. Gliessman.

INTRODUCTION

Multiple cropping is not a new form of agricultural technology but instead an ancient means of intensive farming that has been practiced in many parts of the world as a means of maximizing land productivity in a specific area in a growing season. Generally speaking we observe the practice of planting two or more crops on the same field in a year more commonly in tropical regions where more rainfall and higher temperatures spread over the year are more favorable for continual crop production. As population has increased, increasing the need for agricultural production, the use of multicropping systems is more prevalent. Though the history of multiple cropping is old, the concept has received very little attention from agricultural scientists, and what limited interest exists has come about very recently.

One may ask why this interest has begun to increase so dramatically in such a short time. Food shortages in many parts of the world, as well as the threat of insuficient supplies for others in the near future, continues to stimulate more intensive agricultural investigation in a search for more productive alternatives. As a consequence it appears that we are about to embark on a new phase of agricultural research. Exactly what form it will take is still not known, but the reasons for this new approach are rapidly becoming apparent.

First, we have recently begun to observe a leveling off in yield increases brought about by the types of genetic manipulation that gave us such rapid and impressive yield increases during the "Green Revolution". It is like we have reached a "yield plateau" with the current lines of research and crop selections. Large scale single varieties (for example, some of the International Rice Research Institute-IRRI- varieties of rice most widely utilized) with broad adaptability, produced major breakthroughs in yields, but it appears that such broadly adapted varieties have almost reached their maximum yield potentials. These varieties have been distributed widely, but in many areas with specific soil and climatic conditions, they have not performed as well as hoped, especially on land more difficult to mechanize or irrigate. Thus it is becoming obvious that we must begin to look for varieties with more specific adaptability and selected for specific environments, or else consider alternative cropping systems.

Second, most of the dramatic yield increases during the past few decades have been on the best agricultural lands where soils are good and water control is easily brought about. Future increases in production, therefore, will have to come about through a new and innovative way of managing these highly productive lands, as well as looking for methods of making more marginal lands increasingly productive. Only 20% of Asia rice land, for example, is irrigated, and the new high yielding rice varieties (and also high requiring of fertilizers, water use, and pest control) have not penetrated much beyond this boundary[1].

The third factor is the oil crisis. Oil prices continue to soar, and with them, the cost of fertilizers, pesticides, and fuel needed to build and run farm equipment and move irrigation water. Costs continue to mount for those inputs most responsable for having been able to achieve such dramatic yield increases during the "Green Revolution", and we are faced with the necessity of having to consider other alternatives that might allow us to substitute these high cost inputs with innovative biological or agronomic practices and varieties. Multiple cropping offers one of the most important and promising of these alternatives.

CONCEPTS AND DEFINITIONS

Multiple cropping systems involve management practices where the total crop production from a single piece of land is achieved thorough growing sole crops in close sequence, growing several crops simultaneously, or combining sole and mixed crops in some sequence. The most important aspect of multiple cropping is the intensification of crop production into aditional dimensions other than just the cropping area and the yield achieved there. Multiple cropping includes the dimensions of time and space; for example when two crops share the same space at the same time. Based upon this idea of intensification, a classification of types of multiple cropping systems is presented in Table 1. It should be noted that special emphasis is placed on the distinction between intercropping, where two or more crops are grown at the same time, and sequential cropping, where two or more crops are grown on the same piece of land, but one following the other. Some additional terms used in multiple cropping jargon are presented in Table 2. Agroforestry, as a particular type of intercropping system , will be discussed in more detail below. Also, it is understood that "mixed cropping", "polyculture," and "multiple cropping" are defined equally in this review and will be used interchagably. By combining different aspects of simultaneous and sequential cropping systems, it is possible to visualize a truly complex pattern of different multiple cropping systems. This classification will be used thoughout the following discussion, based upon a recent symposium sponsored by the American Society of Agronomy, in support of the need that currently exists to standardize terminology[4].

THE BASIS OF MULTIPLE CROPPING

A. Yield advantages of crop mixtures:

In areas on the world where multiple cropping is a common aspect of agroecosystem management, it has been shown generally that productivity is more stable and constant on the long term[5, 6].

The farmer is often able to achieve a combined production per unit area greater with a crop mixture as compared to an equal area divided among the separate crop units. In such cases the Relative Yield Total (RYT) is greater than 1.0. It may be that each crop in the mixture yields slightly less that the monocultures, but the combined yield of the mixture of crops on less total land area is the important aspect.

In a study by Trenbath[7] the results of 572 comparisons of crop mixtures demonstrate that the majority (66%) had RYT's close to 1.0, indicating no distinct advantage to the mixture (Figure 1). On the other hand, 20% of the mixtures had RYT's grea

TABLE 1. Definitions of the Principal Multiple Cropping Patterns.

Multiple Cropping: The intensification of cropping in time and space dimensions. Growing two or more crops on the same field in a year.

Intercropping: Growing two or more crops simultaneously on the same field per year. Crop intensification is in both time and space dimensions. There is intercrop competition during all or part of crop growth. Farmers manage more than one crop at a time in the same field.

Mixed intercropping: Growing two or more crops simultaneously with no distinct row arrangement.

Row intercropping: growing two of more crops simultaneously with one or more crops planted in rows.

Strip intercropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact -- agronomically.

Relay intercropping: Growing two or more crops simultaneously during part of each one's life cycle. A second crop is planted after the first crop has reached its reproductive-stage of growth but before it is ready for harvest.

Sequential Cropping: Growing two or more crops in sequence on the same field per year. The succeeding crop is planted after the preceding one has been harvested. Crop intensification is only in the time dimension. There is no intercrop competition. Farmers manage only one crop at a time in the same field.

Double cropping: Growing two crops a year in sequence.
Triple cropping: Growing three crops a year in sequence.
Quadruple cropping: Growing four crops a year in sequence.
Ratoon cropping: Cultivating crop regrowth after harvest, although not necessarily for grain.

Source: Andrews and Kassam (1976)[2].

TABLE 2. Related Terminology Used in Multiple Cropping Systems.

Single Stands: The growing of one crop variety alone in pure stands at normal density. Synonymous with "solid planting", "sole cropping". Opposite of "multiple cropping".

Monoculture: The repetitive growing of the same crop on the same land.

Rotation: The repetitive growing of two or more sole crops or multiple cropping combinations on the same field.

Cropping Pattern: The yearly sequence and spatial arrangement of crops, or of crops and fallow, on a given area.

Cropping System: The cropping patterns used on a farm and their interactions with farm resources, other farm enterprises, and available technology that determine their makeup.

Mixed Farming: Cropping systems that involve the raising of crops and animals.

Cropping Index: The number of crops grown per annum on a given area of land x 100.

Relative Yield Total (RYT): The sum of the intercropped yields divided by yields of sole crops. The same concept as land equivalent ratios. "Yield" can be measured as dry matter production, grain yield, nutrient uptake, energy, or protein production, as well as by market value of the crops.

Land Equivalent Ratios (LER): The ratio of the area needed under sole cropping to the one under intercropping to give equal amounts of yield at the same management level. The LER is the sum of the fractions of the yields of the intercrops relative to their sole-crop yields. It is equivalent to RYT, expressed in commercial yields.

Income Equivalent Ratio (IER): The ratio of the area needed under sole cropping to produce the same gross income as is obtained from 1 ha of intercropping at the same mangement level. The IER is the conversion of the LER into economic terms.

Source: Sanchez (1976)[3].

ter than 1.0, ranging up to 1.7, indicating advantages to the mixtures, and only 14% had less than 1.0, indicating distinct disadvantages. It must be remembered that most of the cases - studied were experimental planting, and not many cases of actual multiple cropping systems. Farmers would tend to chose - the systems which yield more, as we have observed in traditional agroecosystems in the lowland tropical areas of southeastern Mexico.[5,8]

The fact that advantageous mixtures do exist demonstrate the need for detailed research in order to take proper advantage of such systems as alternatives in the near future. But -- for such systems to be consideredas actual alternatives we need to understand thoroughly the biological and agronomic basis responsable for the observed response, as well as the advantages and disadvantages to their use. Before beginning a discussion of each aspect, a basic outline of such characteristics is presented, separated broadly into biological and physical aspects on the one hand (Table 3) and socio-economic aspects on the -- other (Table 4). In many cases it is understood that there may be overlap between the two classifications, yet is is hoped -- that in the course of the following discussion that such aspects will be clarified.

B. General Resource Use:

The most commonly accepted reason for why it is possible to obtain better yields with crop mixtures is due to the fact that the component crops differ enough in their growth requirements that overlap does not take place, or at least is greatly reduced. Such combinations of components can be said to be "complementary"[9].

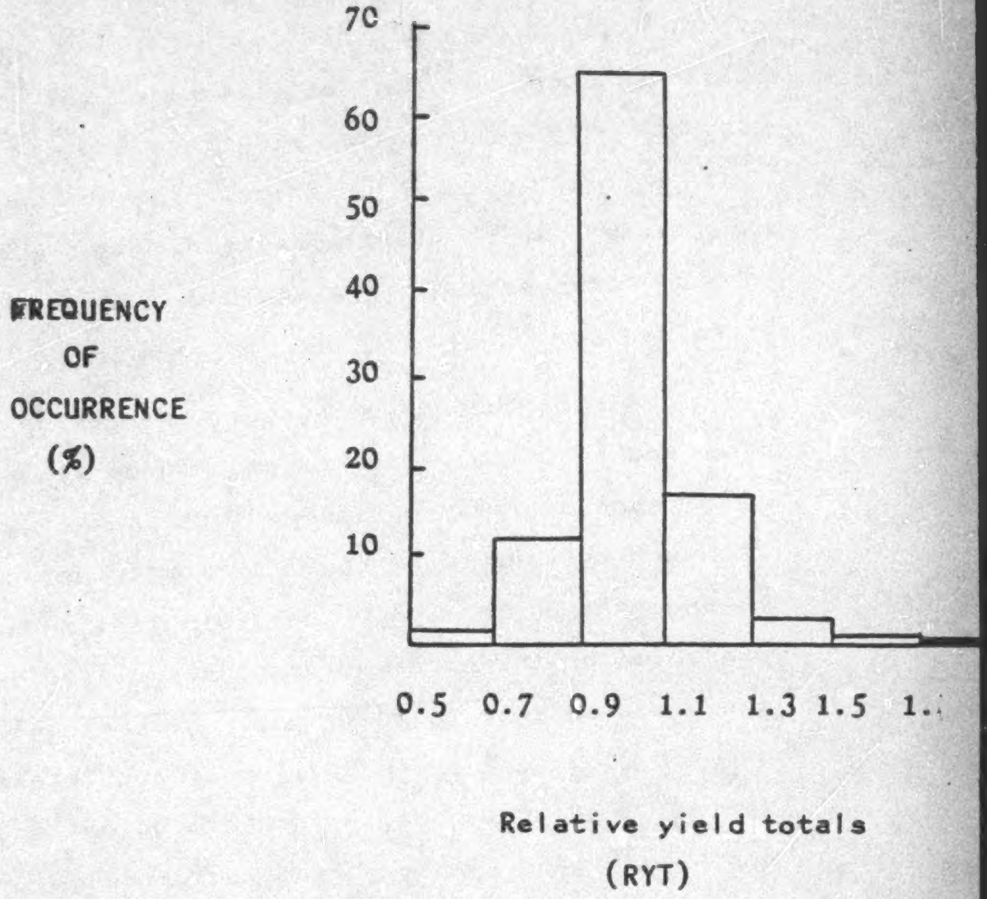

FIGURE 1. Distribution of the relative yield totals of mixtures based on 572 published experiments. From Trenbath (1974)[7].

TABLE 3: Comparative listing of the advantages and disadvantages of multiple cropping systems as compared to sole-cropping or monoculture systems, in regards to biological and physical aspects of the agroecosystem (priority not established).

A. Advantages:

1) It is possible to obtain a better use of vertical space and time, imitating natural ecological patterns in regards to structure of the system, permitting a more efficient capture of solar energy and nutrients.

2) Greater amounts of biomass (organic matter) can be returned to the system, sometimes even of a better quality.

3) There exists a more efficient circulation of nutrients, including their "pumping" from the deeper soil profiles when deeper rooted shrubs or trees are included.

4) Damaging effects of wind can sometimes be reduced.

5) Systems very appropriate for (but not restricted to) marginal areas or areas with considerable variability, because multiple cropping systems can better take advantage of variable soil type, topography, and steeper slopes.

6) Multiple cropping systems are not as subject to variability in climatic conditions, especially extremes of rainfall, temperature, or wind.

7) Reduction of evaporation of water from the soil surface.

8) Increase in microbial activity in the soil.

9) Avoidance or reduction of surface erosion of the soil through physical protection.

10) Fertilizer use can be more thorough by the more efficient capture of nutrients by a more diverse and deeper root structre in the system.

11) Possible to improve soil structure (more stable soil aggregates), avoiding the formation of a "hard pan", as well

as promoting better aeration and filtration.

12) Legumes (as well as a few other plant families) are able to fix and incorporate nitrogen into the system.

13) Heavier mulch cover over the soil aids in weed control, as well as different physical benefits.

14) Better oportunities for biological control of insects and diseases.

15) Crop mixtures better permit the functioning of complex mutualisms and beneficial interactions between organisms.

16) Better use of time, with more crops per unit time in the same area.

B. Disadvantages:

1) Competition between plants for light.
2) Competition between plants for soil nutrients.
3) Competition between plants for water.
4) Possibility for allelopathic influences between different crop plants due to plant produced toxins.
5) Harvesting of one crop component may cause damage to the others.
6) It is very difficult to incorporate a fallow period into multiple cropping systems, especially when long lived tree species are included.
7) It is sometimes impossible, and many times very difficult, to mechanize multiple crop systems.
8) Increase in evapotranspiration loss of water from the soil, caused by greater root volume and larger leaf sur-

face area.

9) Possible over-extraction of nutrients, followed by their subsequent loss from the system with the increased exportation of agricultural or forest products.

10) Leaf, branch, fruit, or water-drop fall from taller elements in a mixed crop system can damage shorter ones.

11) Higher relative humidity in the air can favor disease outbreak, especially of fungi.

12) Possible to favor a proliferation of harmful animals (especially rodents and insects).

TABLE 4: Comparative listing of the advantages and disadvantages of multiple cropping systems as compared to sole-cropping or monoculture systems, in regards to social and economic aspects of the agroecosystem (Priority is not established).

A. Advantages:

1) Dependence on only one crop is avoided, such that the - great variability in prices, market, climate, and pests and diseases do not have such drastic effects on economic outcome of the cropping system.

2) Less need to import energy to the system, as well as pay for externally produced materiales or depend on machinery.

3) Wildlife is favored, such that with a rational exploitation it can constitute an important source of protein.

4) Reduction in the outlay for fertilizers.

5) There is much greater flexibility of the distribution - of labor over the course of the year.

6) Possible to recover investments in much less time, especially in programs of tree production combined with short term agricultural crops.

7) Availability of harvest over a much longer period of time, if not one crop, at least of a series of crops in sequence.

8) In areas and times of high unemployment, multiple cropping systems can occupy much more labor.

9) The farmer of little economic resources can produce a -

large variety of useful products, thus lowering the outflow of funds, such as firewood, construction materials, flowers, honey, crops for home consumption, all of course depending on the type and complexity of the multiple cropping systems.

10) Certain multiple cropping systems permit a gradual change in more destructive farming practices to more appropriate technologies, without a drop in productivity.

11) Promote a return to the land, as well as a maintenance there; of the agriculturalist.

12) In systems which include trees and/or animals, such components can constitute a type of "savings" for the future, while short term crops satisfy immediate needs.

13) Because of their diverse nature, multiple cropping systems promote interdisciplinary activities, stimulating interchange and group activities, leading to more social cohesion on the long term.

B. Disadvantages:

1) The systems are more complex and little understood agronomically and biologically. Statistical designs for experimental analysis are much more complex.

2) In some cases yields are lower, obtaining only a subsistence level production.

3) In many actual economic systems, multiple cropping is not considered to be economically efficient, due to the complexity of activities necessary to make them function.

4) Normally a greater need for hand labor, which in certain economic systems, is considered to be a disadvantage.

5) Some mixed crop systems don't offer sufficient stimulus to lower income farmers to raise their standard of living.

6) For producers with limited economic resources, it may - take longer to recover the entire initial investment.

7) In order to install multiple cropping systems, one encounters opposition from the prevalent social, economic, and political system. In order to permit the new focus in productions may result to be very difficult.

8) There is a shortage of trained personnel (technological - as well as scientific) capable of installing and managing multiple cropping systems.

9) There is a general lack of knowledge or understanding of multiple cropping by "decision makers", affecting especially funding for research to make such systems viable alternatives.

A mixture makes better overall use of available resources. Negative influences (such as competition for light, water, or nutrients) between the component members of a successful multiple cropping system would be considerably reduced. In order to maximize the advantages of such a system, it is important to maximize as much as possible the degree to which one component complements another. With a greater range of requirements between different elements of the mixture, theoretically the greatest advantages would be achieved.

One of the principle ways to achieve such complementary is by varying the crop components temporally, using sequential planting to achieve a multiple cropping system which insures that antagonistic interactions between the components could be avoided. Following a crop with another that has different growth requirements would enable the maximum use of resources. This concept has been used for a long time and forms the basic rational behind crop rotations. The most advantageous use of soil, for example, would be to follow one crop with another that requires different soil nutrients. A subsequent crop would thus be able to absorb fertilizer residues left over by the previous crop, as well as reducing the need for fertilizer applications for the following. For the Eastern United States it has been concluded[10] that such double cropping systems as soybeans after wheat or barley, or the production of silage crops after grain corn or sorghum, can function well. Depending on the length of the growing season numerous sequential plantings can take place during a single year. Such systems require very special management, with timely harvest, use of proper varieties, alteration of the standard planting distance, special selection of herbicides so as to not create antagonisms or residual effects, and also the possibility of using no-tillage planting with certain of the row crops.

Another form of complementing different crop components is through an intensification of the sequential cropping system -- enough to achieve an intercropping system based on relay planting. The same avoidance of overlapping plant growth requirements is gained, as well as the avoidance of direct plant interference, by planting a second crop after the first one has completed the major part of its development, but before harvest has taken place. Relatively little research on relay cropping has been done in the United States, and most often has demonstrated little if any yield advantage (for example, corn into wheat or barley[10]).

On the other hand, in Mexico and Latin America, inumerable examples of relay planting with defintite yield advantages have been reported, especially for corn and beans.[3,11]

Again, the important, and as yet little studied, aspect of relay planting success depends on the correct combinations of timing and varieties so as to avoid shading, nutrient competition, or inhibition brought about by toxicity produced by the decomposition of a previous crop residue.[12]

Finally, the maximum complementarity is achieved by growing two or more crops simultaneously, either in rows, strips, or mixed, but taking advant-age of the spatial arrangement of the different crops, as well as knowledge of their individual growth requirements. Again, most examples of such systems come from outside the United States. One particularly well-documented example is a traditional corn, bean, and squash system in Tabasco, Mexico.[13]

Corn is planted at a density of 50,000 plants/ha, climbing beans in the same hole at a density of 40,000 plants/ha, and the squash intermixed among the rows of corn and beans at a density of 3,330 plants/ha. All are planted at the same time in this case. Beans begin to mature first, using the corn stalks for support; the corn matures second; the squash is the last to mature. Aerial space is divide such that corn occupies the upper canopy, beans the middle, and squash covers the ground in between. Better weed control is achieved, and insect pests are largely controlled by natural enemies (work in progress). Corn yield was significantly higher for the polyculture as compared to different densities of monocultures, but beans and squash suffered a distinct yield reduction (Table 5). Interestingly, the LER (Land Equivalent Ratio) value of 1.73 tells us that the sum of the yields in the mixture can only be equalled in monoculture by planting 1.73 times the area divided proportionally among the three sole crops. The advantage of producing a greater yield altogether on less land is obvious. The much higher total yield of biomass in the mixture is also very important, because much of this organic matter is returned to the soil, bringing important consequenses in soil fertility, humidity conservation, microbial activity, etc., all related to the success of the following crops. Currently, studies are being carried out to try to determine if the higher yields come about due to more efficient resource use, or if in fact some mutually beneficial effect between crop components is taking place, for example, the bean producing nitrogen that the corn can absorb.[14] This example demonstrates the enormous potential that multiple cropping systems offer for the future.

TABLE 5: Yields of corn, beans, and squash (kg/ha) planted in polyculture as compared to low and high densities of each crop in monoculture. Data are presented for grain or fruit yields, as well as for total biomass.

	CROP	MONOCULTURES				POLYCULTURE
Grain or Fruit Yields	Corn: Density	33,300	40,000	66,600	100,000	50,000
	Yield	990	1,150	1,230	1,170	1,720
	Beans: Density	56,800	64,000	100,000	133,200	40,000
	Yield	425	740	610	695	110
	Squash: Density	1,200	1,875	7,500	30,000	3,330
	Yield	15	250	430	225	80

	CROP	Total biomass dry weight				
Biomass Yields	Corn	2,822.9	3,119.4	4,477.5	4,870.9	5,927.2
	Beans	852.9	895.1	842.6	1,390.4	253.1
	Squash	240.9	940.9	1,254.0	801.9	478.3

Total Polyculture Biomass 6,658.6

$$\text{LER (Land Equivalent Ratio)} = \frac{\text{Sum of yields of each polyculture}}{\text{Sum of highest yield each monoculture}}$$

$$\text{LER} = \frac{1720}{1230} + \frac{110}{740} + \frac{80}{430}$$

$$\text{LER} = 1.73$$

Source: Amador, 1980.[13]

C. Specific Resource Utilization, Conservation and Management:

A more intensified land-use system of agriculture will certainly put greater pressures on the available natural resources of our crop and rangelands. Considerable discussion exists at the moment as to the harmful or beneficial aspects of this intensification, and a review of some of the more important aspects can aid greatly in understanding this problem:

1) Microclimate and light: In any agroecosystem a very important aspect of productivity is related to the amount of light converted directly to carbohydrate, hence to vegetative material, through photosynthesis. Each cropping system has a photosynthetic potential, based upon its capacity of conversion[15]. Monocultures, especially of annuals, generally have a much lower potential, because either the plant cover is not complete, or else the soil is occupied only during the growing season, leaving the surface bare of photosynthetic capacity until the planting of the next crop. Light is not like other resources where a reservoir exists, and the plants tap it as the need arises. Rather, is has to be used when it is instantaneously available, thus leaf area becomes a very important factor. A multi-layered polyculture would be able to capture much more light energy, raising efficiency, and potentially, production.

A part from the quantity of light absorbed, its quality is also important. Light that has passed through a leaflayer is altered as certain light waves are absorbed and others penetrate. Plants in the lower layers of the canopy need to be adapted to this alteration - an aspect well studied only in natual vegetation[16]. For cropping systems, light has been studied in detail only for monoculture systems[15] from the point of view of increasing effective photosynthetic leaf area for the single crop. By manipulating species with different light requirements, greater phosynthetic potential can be achieved. This is made easier by using dominant species in the polyculture which do not develop a closed canopy, allowing considerable penetration to the next levels, terminating with the most shade-tolerant plants in the lowest levels. In such a system, the soil surface is effectively covered completely by plants. This manipulation of plant architecture has been studied in detail ecologically[17] and has considerable application in multiple cropping systems.

By insuring that a greater percentage of light is absorbed by the leaf canopy, other aspects of the crop microclimate are also affected. Crops in the lower layers would be subject to less water stress, but care must be taken that root system competition for water does not become a problem. Water loss by soil surface evaporation could be reduced, but transpiration from leaf surfaces might be overly increased in the crop mixture. Soil temperatures would be lowered, an advantage especially in warmer and drier environments, aiding in the conservation and buildup of organic matter in the soil. Protection from wind would be provided for the lower canopy species. Care would need to be taken that the increased humidity in the lower canopies does not promote higher incidence of certain diseases, especially fungi, either of the roots or foliage.

2) Soil-Plant Relations in Multiple Cropping Systems:

Any time that we try to combine 2 or more crops simultaneously in one area, there exists the possiblity for complex interactions between the plants and their soil environment[3].

When total complementarity is achieved, the roots of the component species occupy different soil horizons, reducing considerably the potential competition between species, and increasing the efficiency of total nutrient uptake. In combinations of deep-rooted with shallow-rooted species, especially when trees are planted with grasses or annual crops, the trees are capable of absorbing uncaptured nutrients as they are leached into the soil. Then, through their transport to foliage, they can be deposited on the soil surface again with leaf drop[18].

Intercropping systems have been shown to definitely extract more nutrients from the soil than do single crop plantings per unit area of land. In a very complete study with corn and pigeon peas in Trinidad[19] (see Table 6), various parameters of crop response were measured. Highest single crop yields of grain were obtained in the monocultures, but by summing yields of the two crops planted mixed or in intercropped rows, relative yield totals (RYT) were always higher. Total dry matter production was higher in the mixtures as well. The most interesting aspect is the uptake of nutrients (N,P,K,Ca, & Mg). The total uptake is based on the sum of the two crops together, and in all cases the total nutrient content of the dry matter production was higher for the mixtures, demonstrating the greater extractive capacity of the multiple cropping system. Apparently, for corn and pigeon peas, row intercropping gave the best results, demonstrating that at times two crops together can negatively influence each other, as described in Table 3, but the total yield summed makes up for the reduction. Each mixture needs to be examined in detail.

The greater uptake of nutrients in crop mixtures is said

TABLE 6: Effects of mixed and row intercropping on yields and nutrient uptake of Corn (C) and Pigeon Peas (PP) in St. Augustine, Trinidad, expressed as relative yield totals (RYT).

	Sole Crop		Mixed Intercrop			Row Intercrop		
Parameter	C	PP	C	PP	RYT	C	PP	RYT
Grain Yields (tons/ha)	3.1	1.9	2.0	1.7	1.54	2.6	1.8	1.78
Total Dry Matter (tons/ha)	6.4	5.1	4.2	3.8	1.40	5.0	4.9	1.74
N uptake (kg/ha)	66	119	48	100	1.56	54	127	1.88
P uptake (kg/ha)	13	6	9	5	1.52	11	7	2.01
K uptake (kg/ha)	51	37	37	32	1.59	46	33	1.79
Ca uptake (kg/ha)	10	22	10	15	1.68	9	19	1.76
Mg uptake (kg/ha)	12	14	9	8	1.32	9	12	1.61

Source: Adapted from Dalal (1974)[19], cited by Sanchez (1976)[3].

to deplete the soil more rapidly, but an aspect that needs to be considered is what proportion of this nutrient content is removed from the system with the harvest, as compared to the part reincorporated back into the system. In Table 7 an example is presented of a corn/bean polyculture as compared to the corn monoculture. Total biomass production, as well as yield removed from the system is considerably higher from the mixture -- (10.24 tons/ha vs. 6.68 tons/ha total biomass). The percentage of this total which leaves the system is slightly lower for the mixture (61% vs. 66%), but the actual amount of organic matter returned to the soil in the polyculture (3.98 tons/ha) as compared to the sole crop (2.32 tons/ha) demonstrates that although more material is produced by the intercrop system, a greater amount returns, possibly offsetting any increase in extraction of soil nutrients and permitting the long term management of the system.

Another way to increase the return of nutrients to the system is to plant "nurse plants". These plants do not contribute directly to the biomass harvested and removed from the system, but their capacity to capture nutrients and continually recycle them in the soil would be of definite advantage. Local farmers in Tabasco, Mexico, use this concept in the management of weeds,[20] leaving those that don't interfere with the crops and removing those that are harmful. The constant cover over the soil gained by such a practice permits, apart from nutrient conservation, the maintenance of better soil structure, conservation of water, more microbial activity, and over the long run, less need for the application of chemical fertilizers. By including plants which "trap" nutrients, such as legumes, such benefits can be improved even more. The wide-spread use of legume trees for shade in coffee and cocoa plantations is a classic example[21].

TABLE 7. Biomass distribution (in tons/ha) of dry matter in a corn/bean polyculture as compared to a corn monoculture, in Tacotalpa, Tabasco, Mexico.

Crop	Roots	Crown	Leaves & Stem	Grain[a]	(A) Total	(B) Removed Matter	$\frac{(B)}{(A)}$ %	(A)-(B) Total Reincorporated
Corn	0.49	0.60	2.29	4.76*				
+					10.24	6.26	61%	3.98
Beans	0.15	0.00	0.45	1.50*				
Corn Alone	0.34	0.41	1.57	4.36*	6.68	4.36	65%	2.32

[a] Weight of grain of corn is unhusked, including cob and husk, in the manner that the harvest is removed from the field in this region.

* Indicates the removed portion of the biomass.

Source: Adapted from Gliessman & Amador[5].

3) Water Use in Multiple Cropping Systems:

Any discussion of water use involves a consideration of rooting patterns. It can be supposed that in multiple cropping systems, especially with several crops with differently arrayed root systems, that a greater volume of the soil will be occupied and thus water use efficiency will be higher. This would be useful on the one hand in areas where water supplies are limited, and on the other to make more complete use of costly irrigation water. It has been proposed that cover crops in orchards stimulate deeper rooting by the trees[22]. Different peak periods of water use in the crop mixtures would avoid competition and increase over-all water use efficiency[23]. A crop such as corn which uses relatively little water in the early stages of development could be interplanted with an early maturing crop in order to take advantage of the unused moisture[24].

In areas where water is severely limiting, one would have to be careful not to plant crops with over-lapping water requirements, because in very dry years, one member of the mixture could be outcompeted by the other[25]. Combining two crops with slightly overlapping water needs, on the other hand, could be used to an advantage in areas with widely fluctuating rainfall regimes. In a dry year, one component would be favored, and in a wet year the other, guaranteeing profitable harvests of at least one or the other every year. Studies on water availability in each region, coupled with studies of water needs of each component crop of multiple cropping systems are critical for proper management.

The important effects of multiple cropping on the conservation of water and soil are well known[26,27], primarily achieved through the maintenance of a more complete vegetative cover over the soil. It is important to remember that apart from improving cover while the crop is growing, multiple cropping systems aim - towards maintaining this cover between harvests. This is achieved by reducing the time between harvest and replanting in sequential systems, planting a new crop into another in relay cropping, and continually interplanting in an intercropped system. The use of trees, either as windbreaks, or for soil stabilization on eroded hillsides or in areas subject to desertification, can be enhanced greatly by combining them with crops or pasture grasses - (see discussion on Agroforestry).

In summary, although it appears that multiple cropping systems use more water, their ability to obtain water not available to monocultures, use the water more efficiently, and contribute - significantly to soil conservation, demonstrate a further potential for their more widespread use.

4) Pest, Disease, and Weed Relations:

As can be seen in Table 3, there exist possiblilities for - multiple cropping systems to be both advantageous and disadvan - tageous in relation to problems of pests, diseases, and weeds.[28,29] The problem has to do with the great complexity of environmental factors and their dynamic interactions within the cropping sys - tems, where capital is not available or technical assistance has not been accepted, we observe that the main means of control of pest, disease, and weeds is achieved on the one hand through biological control, and on the other through the management of a -- great diversity of cropping patterns, both in time and space[30].

It has been suggested that multiple cropping systems permit such a control because they are much less subject to attack.[28,31,32] This comes about because the mixed cropping system (1) prevents spread of diseases and pests by separting susceptible plants, (2) one species serving as a trap crop, protecting the others, (3) associated species serve as a repellant of the pest or disease to which the other crops are subject, and (4), a greater abundance of natural predators or parasites of pests due to a higher diversity of adequate microsites and alternate prey. However, we can site reasons for which a multiple cropping system may be more susceptible to attack: (1) reduced cultivation and greater shading due to the presence of associated species, (2) associated crops serve as alternate hosts, and (3) crop residues from one crop may serve as a source of inoculum for the others. All of these advantages and disadvantages can exist, and much further study is necessary to achieve the combinations which give the most positive results.

A few examples might serve to demonstrate the specific potential of multiple cropping for biological control. In one study[34] it was shown that the planting of a locally used medicinal herb (*Chenopodium ambrosioides*) in sequence with corn or beans, reduced the incidence of nematode populations in the soil, demonstrating a potential for reducing attack on the roots of the bean and corn crops. Substances toxic to the nematodes were liberated into the soil by the herb, wherein the nematodes were inhibited. In another study, yields of cotton untreated with insecticides, but interplanted with sorghum, were 24% higher than the sprayed monocultures. The reason was that sorghum served as microhabitats for cotton bollworm predators[35]. In another case fall army worms on corn associated with bush beans were less a problem than on pure-stand corn[36]. In an incidence in which beans intercropped with corn were attacked less by rust as compared to beans in pure stands, it is felt that corn functions as a barrier to the dissemination of the fungal spores[37].

Weeds, on the other hand, present another problem. It has been reported that weeds are much less a problem in multiple cropping systems, especially in intercropping,[29] the idea being to occupy the space normally available to weeds, with other crops. The aggressive nature of weeds is well known[38], but recent work has begun to show that weeds can fill an important ecological - role in cropping systems, by capturing unused nutrients, protecting the soil, altering soil fauna and flora, serving as trap - plants for pests and disease, and changing the microhabitat to - allow for high populations of pest predators and parasites.[39,40], The understanding and use of a "non-weed" concept by farmers in rural tropical Mexico[20], where each is classified according to - positive or negative effects, demonstrates that we need to understand in more detail the biological functions of each component of the agroecosystem in order to establish the structure that -- will allow adequate weed, pest, and disease control. If part of this control can be achieved by merely manipulating the crop mixture in time and space, great strides towards a more efficient - agricultural management can be made.

5) Mutualisms and crop coexistence:

In natural ecosystems it has become apparent that a great - number of interactions between different species are mutually beneficial for those organisms involved, leading us to believe that there is a strong selective pressure operating to select combinations that coexist rather than compete.[41] On the long term, such a coexistence permits a more efficient use of resources, with the component organisms aiding one another rather than interacting negatively. More energy can be put into growth and reproduction rather than into direct competition.

To a certain extent, nurse crops or companion plants function in this way. Legumes, because of their symbiosis with nitrogen-fixing bacteria, can coexist with corn without competing for nitrogen. Infact, part of this nitrogen may be available for the corn[14], reducing overall need for fertilization. Studies with coffee and cocoa shade trees have demonstrated the same relationship; the trees provide shade, nitrogen, and an organic mulch over the soil[21].

As already mentioned in previous sections, the presence of one crop may have beneficial effects on others through alteration in the microclimate, pest and disease protection, etc. Thus, apart from looking for crops that complement one another by avoiding overlap in requirements, we need also to look for crops that are interdependent to the extent of mutually benefitting from the association. Crop selection programs are faced with a very stimulating challenge in this respect.

6) Use of Space and Time:

As mentioned in the beginning of this review, one of the most important aspects of the management of multiple cropping systems is the facility they offer for the intensification of production through manipulation of space and time. It is within this context that the previously mentioned aspects of resource use takes place. By achieving the most ideal combination of the interaction of the two, we will achieve the greatest productivity. On the one hand we attempt to occupy the available resource space as efficiently as possible, combining species that complement each other in relation to the availability of resources, yet attempting to avoid overlaps that lead to negative interactions.

Resource use in space is then combined with its use in time, trying to achieve constant use of those resources available.For this reason multiple cropping systems are intensified by sequential, relay, and mixed planting, establishing constant resource use within the environmental limits imposed by the ecological conditions of each region. In this sense, we can even visualize the possiblity of including cold resistant trees in association with annual crops or pasture, such that during the winter the trees continue to occupy the area. Thus, any yield reduction brought about during the normal frost-free growing season is more than compensated for by the long term tree production.

Additionally, multiple cropping systems permit greater stability in production, despite variability in climate or physical factors in the planting area. This is achieved by the security that the conditions in one location and for one growing season will be adequate for at least one member of the multiple cropping system. Now that the more homogeneous, better drained and structured soils have been put into production, the more variable marginal lands will require a special technology in order to make them produce. We cannot consider for the moment massive programs of soil and water manipulation in order to install mechanized high-yielding monocultures. To do so is currently economically, if not ecologically, prohibitive. The basic framework in available with a focus on multiple cropping. Innovative combinations need to be searched for and tested.

D. Agroforestry: a Multiple Cropping System:

Agroforestry is a technology of land management that implies the combination of forest trees with agricultural crops, with - animal raising, or any combination of the two. Combinations can be simultaneous, or staggered in both time and space. The major- objective of agroforestry is to optimize production for each unit of surface area, keeping in mind the need to maintain long term - yield[42,43,44]. Small scale traditional agriculture has always - included trees as integrated elements of farm management, but only recently has interest been revitalized in the application of - agroforestry practices into modern agriculture.

The renewal of interest in agroforestry systems has its basis in many of the same reasons observed for multiple cropping - systems in general. The ever-increasing demand for production, - yet the rising cost of obtaining it, has forced us to look again to some systems used commonly in the past in developed regions,- and still in use in less developed areas. The explosive demand for firewood and lumber has placed incredible pressures on the - forested areas of the world, especially in tropical and subtropical regions. Deforestation continues at an accelerated rate.[45,46] But programs of reforestation or forest manipulation involving a multiple use focus, do not allow for the satisfying of basic needs for food, clothing, and other necessities which come - from our crop and range lands. Thus it would seem logical that pressure for both forest and agricultural products would stimulate their combination in agroforestry systems.

Agroforestry practices can be broadly classified into three types[47]: (1) combined agrosilvicultural systems, (2) combined fo restry and grazing, and (3) simultaneous combinations of forestry with crops and grazing. Examples of each of these classifications are presented in Table 8. The focus varies from soil improvement, erosion control, wind breaks, and shade on the one hand, and on lumber, firewood, and reforestation on the other. The combinations are essentially unlimited, depending on the demands and needs for each region. At first glance it might appear that agroforestry systems are most applicable on marginal lands, of steep slopes, poor soils, or areas with widely fluctuating rainfall regimes. But we must also consider the widespread application of agroforestry even for prime agricultural or grazing land, because as mentioned before, production needs to be increased -- both by opening up new areas as well as by looking for innovative ways to increase productivity of already exploited lands.

The principle limitations to widespread use of agroforestry practices at the moment are economic and technological. Ecologically, the advantages are well known (Table 3), but technically we still do not have the information necessary to begin inmediate implementation. With the present focus in agriculture aimed at maximizing single crop yields, and therefore economic profits from their management, there is as yet a lack of acceptance of the idea that yields need to be thought of more on a long term, diversified basis. Agricultural research has not yet accepted the challenge that such an integrated focus to forest and farm management requires.

E. Socio-economic Implications of Multiple Cropping Systems: Perspectives for the Future:

In all of the aspects of multiple cropping systems that this review has considered - yield, resource use, pest and disease -

TABLE 8: Classification and Examples of Agroforestry Technologies, with a description of the benefits and aims of each system.

I. Combined Agrosilvicultural Systems (Trees with crops):

1. Agrosilviculture - establishment of trees, intercropped with agricultural crops during initial stages of tree growth, until tree canopies close and force the elimination of the cropping. Production available in early stages of tree development, and cultural activities simultaneously beneficial for both crops and trees.

2. Forest trees of commercial value in crop systems. Maintenance of trees in crop areas, either planted or natural, at low densities so as to not interfere, yet of value in the future.

3. Fruit trees in crop systems. A system that allows for fruit production and grain or vegetable production simultaneously.

4. Trees that serve as shade for certain crops or improve the soil through nitrogen fixation, organic matter incorporation, mulch, and microclimate modification.

5. Trees used as hedge rows, fence lines, or windbreaks around cropping areas, whose management is intimately linked with the needs of the crops.

6. Trees around rivers, lakes, or artificial reservoirs or tanks, integrated with fish or waterfowl management, providing shade, food, and roosting.

II. Combined Forestry and Grazing Systems (Trees with grasses):

1. Grazing or forage production takes place within forestry plantations, aiding in avoiding weed or brush build up, lowering fire risk.

2. Grazing or forage production in young natural forests, with same advantages as above.

3. Forest trees of commercial value in pastures, either planted or natural, at densities that do not interfere with the pasture species.

4. Timber trees in pasture, either planted or natural, with the capacity to fix nitrogen and improve soil, thus lowering the need to fertilize, at the same time of commercial value.

5. Trees in pastures that provide shade for the animals and aid in improving the soil through nitrogen fixation and nutrient extraction from deeper soil levels.

6. Trees, either in or around pastures, or in forests, that produce folliage of forage value for animal consumption. Can allow the reduction of feed supplement for animals.

7. Fruit trees in pastures, allowing for commercial production of both fruits and animals.

8. Trees around pastures as hedgerows, fence lines, or windbreaks.

III. Simultaneous Combinations of Forestry with Crops and Grazing:

1. Forest plantations planted with crops and grasses, permitting the management of grazing animals, either free to wander or enclosed in specific areas.

Especially adapted to smaller animals, such as ducks or pigs. Requires close control of activities and use of specific crops.

2. Trees associated with crops and grazing, either planted or natural, in densities that will not adversely influence the crops. Example of scattered trees in and around cropping areas that can be periodically pruned and used as forage for animals, with the timber harvestable at some later date.

3. Hedge rows or living fence lines around rural communities, serving as shade, windbreak, property divisions, forage, fruits, timber, and firewood. In this sense, the system takes on a truly multiple use aspect.

Source: Combe & Budowski (1979)[47].

control, weeds, use of space and time, types of planting systems, much of the evidence indicates that generally there are more advantages than disadvantages of a biological, physical, or agronomic nature. But we need to consider the social and economic implications of the possible more widespread use of multiple cropping systems in presentday agriculture.

As can be seen in Table 4, the types of advantages derived from multiple cropping are many and varied. With a greater diversity of crops, a farmer is less effected by market fluctuations, being able to shift from one crop to another depending on price and demand, at the same time having the harvest spread out over a longer period of time. Less dependence on outside sources of energy for system management has obvious advantages , especially in areas where capital is limited. Labor, instead of having to be concentrated in certain specific periods of the year, can be more evenly distributed, an aspect very important in relation to the migrant farm worker problem. In times of higher unemployment, multiple cropping systems can offer more and steadier work.

Most of the disadvantages of an economic nature are derived from our lack of experience and knowledge with multiple cropping systems. Reported lower yields, complexity of activities involved in their management, the higher labor demands, and the difficulty in mechanizing such systems are all important components which discourage modern farmers from participating in multiple cropping practices. An important aspect of this hesitation or resistance comes from the emphasis on large profits that governs so much of modern agriculture today. Maximum profits on the short term, rather than being concerned with maintaining constant income on the long term, governs the decision making process on most American farms -

today. But with the incredible rise in farm costs, a new focus is necessary. All of these increases cannot be passed on to the consumer. Many of the advantages listed previously of multiple cropping systems in this aspect definitely need to be stressed more for use on farms today. Smaller farms, with a greater diversity of products and activities can function quite profitably, due to less dependence on high cost energy inputs. Lower costs mean food can be produced at a lower price, the benefits being received in this case by the general population.

Socially speaking, with smaller farms, we need more farmers. To a certain extent multiple cropping systems mean a return to the land, with the incentives necessary to keep the farmers there. The great diversity of activities in multiple cropping systems will necessarily promote an increase in interdisciplinary activities in their investigation, installations, management, and amplification into present day agriculture. This stimulation of interchange and collaboration on the long term can lead to greater social cohesion. Rural regions once again take on the social importance they enjoyed in the past. The problems of lack of trained personnel, and social, political, and economic restrictions on multiple cropping systems, all can be overcome by thorough and conscientious programs of research aimed at determining the proper methods, varieties, and practices necessary. The belief that multiple cropping is only suitable for maginal or underdeveloped regions ignores the fact that just a relatively short time ago, such systems were the most common type of agriculture, but have been replaced by monoculture systems dependent on the use of massive quantities of inexpensive high energy inputs. For the moment, this time has passed, and the need to relearn from the past in order to reshape agriculture for the future, provides the greatest challenge for present agricultural research.

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APPENDIX

Photo 1. Example of a Corn/Bean Mixed Cropped System. Turrialba, Costa Rica.

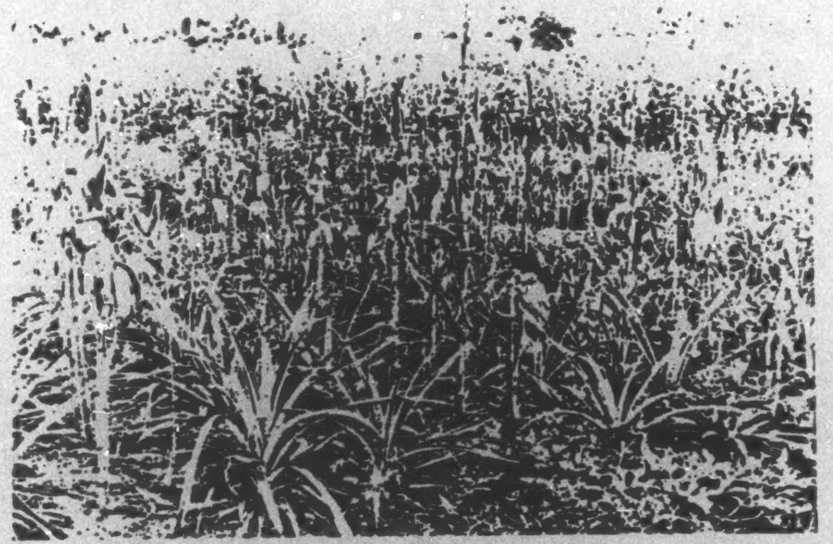

Photo 2. Example of a Corn, Pineapple, watermelon relay intercropping system, Turrialba, Costa Rica.

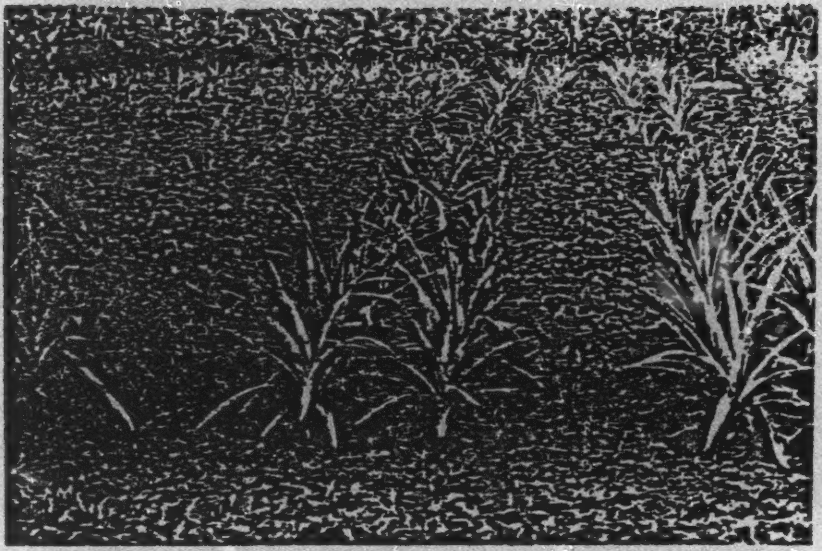

Photo 3. Example of a Pineapple/Pigeon Pea Intercropping System, Turrialba, Costa Rica.

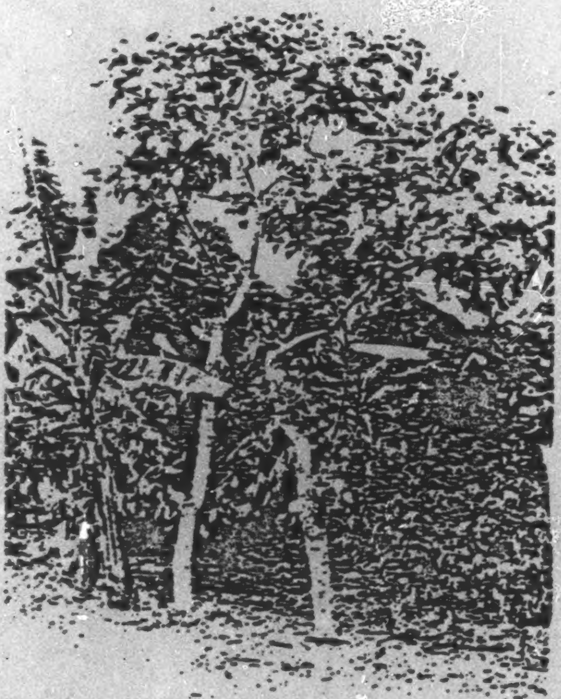

Photo 4. Example of an Agrosilvicultural System of Agroforestry, with coffee, cocoa, bananas, and a legume shade tree. CATIE, Turrialba, Costa Rica.